ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Vol. 8 OCTOBER-DECEMBER, 1954 No.

Semi-Popular Articles

Original Research

Utilization Abstracts

Book Reviews

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Founded, managed, edited and published by

EDMUND H. FULLING

at

The New York Botanical Garden

Economic Botany is published quarterly. Subscription price per annual volume everywhere is $5.00; price per single copy is $1.50. Subscriptions and correspondence may be sent to the office of publication, Box 749, Lancaster, Pa., or to Economic Botany, The New York Botanical Garden, New York 58, N. Y., and checks should be made payable to Economic Botany. Typescripts should be double-spaced. Photographs will be considered only if of high photographic quality.

Published Quarterly, one volume per year, January, April, July and October
Box 749, Lancaster, Pa.

Entered as second-class matter March 13, 1947, at the post office at Lancaster, Pa.,
under the act of March 3, 1879.

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

VOL. 8 OCTOBER–DECEMBER, 1954 NO. 4

Semi-Popular Articles

Original Research

Utilization Abstracts

Book Reviews

Isolation and Utilization of Vegetable Proteins

Among these proteins, those of soybean are isolated in the United States to the extent of about 30 million pounds annually, more than half of which are used in pigment coating of paper. Others, also discussed in this article, are those derived from the seed of flax, sunflower, castor, peanut, cottonseed and corn.

ALLAN K. SMITH

Northern Utilization Research Branch,[1] Peoria, Illinois

Introduction

Vegetable protein isolation on a large scale for use in industrial processing operations is comparatively new, having its beginnings in 1935 in a small plant in Chicago. The development of a process for vegetable protein isolation was preceded by the use of vegetable protein concentrates for plywood glue, in the form of soybean meal containing 40 to 50 percent protein, by the Douglas fir plywood industry of the Northwest in the early 1920's. In contrast to the recent development of vegetable proteins, it is claimed that Egyptian cabinetmakers used glue from animal protein sources more than 3,000 years ago.

Looking backward it is easy to see that the slow development of protein utilization, even in recent history, is attributable to the highly complex nature of protein and especially to the complicated structure of the protein molecule. Even today the scientific aspects of protein utilization are " thin ", and new developments on protein utilization depend more on " trial and error testing " than on specific knowledge of protein reactions. The chemistry of proteins lags far behind the chemistry of the other two classes of major agricultural chemicals produced in such abundance by nature, namely, the carbohydrates and fats.

It is convenient to classify protein utilization as feeds, foods and industrial proteins. On a tonnage basis the proteins used for industrial purposes are a rather insignificant part of the whole. Nevertheless, though small in tonnage production, the isolated proteins have many and important applications.

Another pertinent way of viewing the protein picture is from their origin, i.e., are they animal or vegetable? Of course, all animal proteins are ultimately derived from vegetable proteins with the animal as the converter. It is important to remember this relationship in the economy of protein utilization and that the process of building one pound of animal protein requires six to ten pounds of vegetable protein, this wide variation being dependent partly upon genus of the animal and partly upon the composition of the diet. Thus it is evident that basically the vegetable proteins are cheaper than animal proteins.

The great demand for animal proteins for food limits their sources for industrial purposes to the inedible residues from meatpacking houses, to the fishing industry and to proteins recovered from temporary surpluses of the dairy industry. Industrial proteins of animal origin (39, 79) are: (*a*) the meatpacking by-

[1] One of the Branches of the Agricultural Research Service, U. S. Department of Agriculture.

products—animal glue, and photographic and pharmaceutical gelatin—made principally from hides, connecting tissues, cartilage, bones, trimmings from cattle and calves, and blood albumen; (*b*) the dairy byproduct casein from skim milk; (*c*) egg albumen; and (*d*) a small amount of fish glue derived from fish skins, heads and trimmings obtained from canneries and fisheries. The annual supply of various types and grades of industrial and edible gelatin amounts to about 190 million pounds with edible gelatin accounting for 25 percent of the total.

The non-fat dry-milk solid obtained by evaporating the water from skim milk is in much more demand for food products than casein for industrial uses. Present production of non-fat dry milk is about 900 million pounds (about 70 percent used for food), compared to a domestic production of casein of about 20 million pounds. However, the domestic casein supply is supplemented by importations of about 40 million pounds, mostly from Argentina.

It is evident that the supply of industrial proteins from animal sources has definite limitations which are not susceptible to ready expansion, and that any major increase in industrial protein production must come from vegetable sources.

Vegetable Protein Sources

Vegetable proteins occure widely in nature—in leaves, stems, bark, roots and seeds of plants. H. B. Vickery (153) has reviewed the general occurrence of plant proteins, the early history of plant protein chemistry, and the present status of fundamental protein research. However, Vickery does not deal specifically with the possible sources of industrial proteins, protein properties important to industrial uses, nor methods used for large-scale isolation.

Vegetable protein concentrates are mostly the results of processing oilseeds for oil and meal, and are used primarily in the form of mixed feeds for feeding animals. The notable exceptions are corn germ and corn gluten which are byproducts of the wet milling of corn for starch and dextrose, and wheat gluten derived from wheat starch production. Much of the wheat gluten and some corn gluten are channeled into the production of monosodium glutamate, a comparatively new product for this country, which is used for enhancing food flavors. The monosodium glutamate (MSG) originating in Japan under the name " ajinomoto " is especially popular in canned and dried soups, as well as for seasoning meats, cooked vegetables and vegetable salads. The MSG shaker is rapidly finding a place in the home kitchen beside those of salt and pepper. Smaller amounts of wheat gluten are used to make a tasty product somewhat resembling pork chops.

Table I gives a list of oilseeds, their proximate analysis on a moisture-free basis, weight per bushel, and tons of concentrate produced from their seed for the year 1951–52. On a world wide basis, the production of soybeans far exceeds any other oilseed crop with second and third places held by peanuts and cottonseed, respectively. Prior to the adoption of soybeans as a major crop in the United States, peanuts led all other oilseeds in world production, but at the present time the United States production of soybeans on a tonnage basis is nearly equal to the world production of peanuts.

The analytical data in Table I are averages from a large number of seed samples. Values for individual samples vary widely from these averages. For example, the data of Cartter and Hopper (33, 154) for ten varieties of soybean over a period of five years shows protein values ranging from 36.62 percent to 53.19 percent ($N \times 6.25$); the oil

for these samples varies from 15.39 to 22.94 percent; and higher and lower values for both the oil and protein are not difficult to find in other sources. The variations in seed composition have come to be a recognized property of plants. Variations in composition depend most of all on varietal differences with some additional influence due to climate and soil.

Because of the high price of oil during the war and subsequent years, plant breeders have been increasing the oil content of our commercial oilseed crops as well as increasing yields and developing varieties with greater disease resistance. Increase in oil usually is balanced by a loss in protein. The oil normally sells on a pound basis at two and one-half to three times the price of the meal, so seed value increases with increase in its oil content, and the basic value of the seed depends more on the oil than protein. During the war years and immediately thereafter, the price difference in favor of the oil was much greater than now; however, the present trend in the equilibrium between these two important products, in relation to their supply and demand, appears to be toward the protein.

Calculations from the data in Table I show that the total protein available from oilseed processing is approximately 20 billion pounds; on a population basis this is about 50 pounds per capita. With the exception of copra, which is imported, and safflower, all of these oilseed meals and the corn gluten have been investigated for their suitability as a base material for protein isolation. However, soybeans and corn gluten are the only concentrates presently used to supply isolated protein for non-food uses.

TABLE I

U. S. Production of Oilseeds and Their Protein Concentrates for 1951–52; Proximate Analysis on Moisture-Free Basis and Percentage of Seed Coat

Seed	Seed production 1951–52	Production of protein concentrate 1951–52	Analysis of seed, moisture-free basis			Seed coat hull
			Protein ($N \times 6.25$)	Oil	Ash	
		Tons × 1,000	%	%	%	%
Soybeans (in bu.—60 lbs.) ..	286,636 [1]	5,704	43	20	5.0	8
Cottonseed (in tons)	6,325 [1]	2,543	21.5 [2]	21.6 [2]	4.2 [2]	36 [2]
Cottonseed kernels	......	....	32.5	31.8	4.7	..
Flax (in bu.—56 lbs.)	33,802 [1]	495	27	42	3.4	41
Flax embryo	......	....	30.3	55.7	3.5	..
Peanut (in tons)	797,512	150	27 [3]	48 [3]	2.5 [3]	25
Castor bean (in lbs.)	100,000	....	18.9	49.5	2.8	30
Castor bean kernel	......	....	24.4	68.6	2.3	..
Safflower (in tons)	6,000	6	2.16	32.8	3.19	49
Sunflower (in tons) [4]	3,300	....	3.12	29.3	3.43	43

[1] Times 1,000.
[2] Acid delinted.
[3] Data for meats.
[4] World production.

This review includes the more important references, exclusive of patents, which contribute to commercial methods for isolating proteins from flaxseed, sunflower seed, castor beans, peanuts, cottonseed, soybeans and corn gluten.

The principal proteins in oilseeds are globulins and glutelins, with lesser amounts of albumins; they contain no

identifiable prolamines. The alkali-extraction method for dispersing the protein from oilseed concentrates results in isolating a mixture of proteins which are more or less modified by alkali and other chemicals used in processing; the final product may, therefore, be considered a "derived protein". Prolamines are characteristic of, and found almost exclusively in, cereal grains, the one known exception being an alcohol-soluble protein occurring in milk.

Raw Materials for Protein Isolation

Protein concentrates intended as base material for protein isolation must be processed with a minimum of protein denaturation. The rate of protein denaturation (20, 16, 17, 140) is relatively slow at moderate temperatures when the moisture content of the meal is low, but at about 80° C. and above, and at normal or higher moisture contents, denaturation is rapid. Oilseed meals that are processed by screw and hydraulic press equipment are thus excluded as materials for protein isolation, since the elevated temperatures of such operations badly denature and discolor the protein. Concentrates intended for use in protein isolation are thus limited to solvent processed meal.

Modification of the normal process used for producing stock feed (14, 28, 90, 40, 113) is necessary in order to meet the requirement of high protein dispersibility. In mills producing stock feed, the solvent is usually removed at elevated temperatures and the meal may be treated further with live steam to destroy toxic or antinutritional components which may be present. Steam treatment is essential in producing stock feed from cottonseed, soybeans and some other meals intended for feed. It adversely affects protein dispersibility and the color of the isolated protein. Belter and Smith (20) have shown that in commercial processing with low-boiling hydrocarbon solvents (b.p. 30–75° C.), very little denaturation occurs in the preparation of the soybean flakes and in the solvent extraction part of the process which includes cracking, dehulling, conditioning, flaking of the beans and extraction of the flakes. Most of the denaturation occurs in removing the solvent and in steaming or "toasting" for improvement of nutritional value.

A comparatively recent innovation in solvent removal is to pass the solvent-wet flakes through superheated solvent vapors, thus avoiding the use of moisture and obtaining a minimum of protein denaturation. A flash type of desolventizer of excellent design, using superheated solvent vapors as the heating medium, was recently described by Belter, Brekke and Smith (19). Figure 1 shows the dispersibility of nitrogen components in water for undenatured soybean meal and the change in dispersibility which occurs when it is treated with steam at atmospheric pressure. These curves, taken from Belter and Smith (20), can be used as a guide in establishing specifications for procuring soybean meal for protein isolation. The variables affecting the dispersion of nitrogen compounds from soybean meal, such as mechanical agitation and temperature of extraction, have been described by Smith, Belter and Johnsen (135) who have established a tentative method for measuring denaturation. The factors affecting soybean protein isolation have corresponding factors in the isolation and evaluation of the other vegetable proteins.

General Procedures for Protein Isolation

Methods for isolating industrial proteins are usually different from those for isolating pure proteins for study of their individual properties. Isolation of a specific protein involves dispersing in neutral salt solutions and precipitation

by dilution, by dialysis, by salt dehydration, and sometimes by solution or precipitation with organic solvents. Such procedures are generally too expensive for commercial operation. For economic reasons, high yields, which are usually obtained only by alkaline extraction of the protein, are more important than protein purity and specificity, and a mixture of proteins may be as useful as a highly purified one. Even some denaturation or degradation of the protein may have an advantage for a particular use. For specific industrial application it is often necessary to modify the protein to give some particular property such as dispersibility, color, foaming capacity, wettability, adhesive strength, viscosity, gel strength, colloid protective properties and a particular molecular size or shape. The protein processor, as well as the user, may have little or no fundamental information concerning their products or the chemical reactions which occur in producing them. Nevertheless he usually modifies the size and shape of his protein molecules by empirical methods to arrive at the desired end product. As our fundamental knowledge of proteins develops, it should be easier to process proteins for special applications and to better understand their utilization.

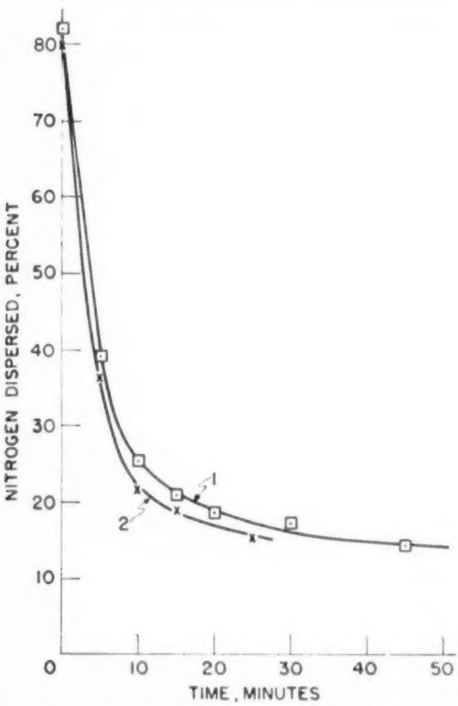

FIG. 1. Change in nitrogen dispersibility of soybean meal in water with increasing time of atmospheric steam treatment. Curve 1, the flakes steamed after solvent extraction of the oil. Curve 2, the flakes steamed before solvent extraction.

Flax Seed (*Linum usitatissimum* L.). Flax is grown for both seed (46) and fiber (124). Flax for textile use is a different variety than flax for seed, and textile varieties have not been grown in this country in recent years except on an experimental basis. The bast fiber from seed-flax straw or tow is now used in the manufacture of cigarette paper, lens paper (121) and other paper products where a long, strong and lintless fiber is required. Seed flax is cultivated mainly for its highly unsaturated oil for use in paints, varnishes, linoleum, oilcloth, printing ink, putty and other drying-oil products. Linseed meal is a valuable animal feed, especially for cattle when a fine coat is desired.

Production of flaxseed in the United States has varied widely; a maximum of 54.5 million bushels (56 lb.) was attained in 1948. Since then there has been a decline to 31.0 million bushels in 1952. Since 1947 the United States has been the world's largest producer of flaxseed (58), with Argentina ranking second.

Because flax yields are low, the price of the oil is usually higher than that of semi-drying and edible oils of lower iodine numbers. On a moisture-free basis, flax contains 40 to 43 percent oil, 26 to 28 percent protein, and about 3.5 percent ash. The moisture-free, sol-

vent-extracted meal contains 40 to 48 percent protein and is a possible source for isolated protein. The low yields of flax with the resulting high price for the oil are economic factors that have endangered the future of this crop in this country. Lower cost semi-drying oils, such as soybean and safflower, have replaced substantial amounts of linseed oil, and in recent years government support of flax production has been necessary to maintain adequate supplies. The development of important industrial uses for the protein or of the flax mucilage would help in the economic production of this crop.

The first publication on linseed protein isolation was by Osborne (108) in 1892. However, he had little concern for utilization of the protein other than as stock feed. Vassel and Nesbit (152) studied the proteins of flax and proposed the name " linin ", from the botanical name *Linum usitatissimum*, for the major protein component, and " conlinin " for another identifiable globulin.

Smith, Johnsen and Beckel (139) investigated the yield and properties of flax protein isolated by alkali extraction and acid precipitation. They reported that the mucilage and the dark-colored pigments occurring in the hulls are water-soluble and were found to be very objectionable factors in commercial protein production. The mucilage interfered with settling of the precipitated protein, while the pigments reacted with the protein to give an undesirable color. They found the seedcoat constituted about 41 percent of the seed and that the 59-percent meats contained 96.7 percent of the oil. They were able to separate a high percentage of the hulls from the meats by passing the solvent-extracted meal (at eight percent moisture or above) between smooth rolls followed by screening to give a fraction containing about 48 percent protein. Upon extracting the protein-rich fraction with sodium hydroxide, clarifying the protein dispersion in a centrifuge, and precipitating with acid, yields on the basis of the weight of the decorticated meal fraction were as high as 38 percent. Since the protein extraction was made on a mechanically decorticated portion, the yield on the basis of the total protein in the original meal (containing hulls) is reduced to about ten percent.

The nitrogen content of the flax proteins varied with the method of isolation or fractionation. Alkali-extracted and acid-precipitated proteins gave the highest protein yields with low nitrogen values of about 14 percent. The proteins isolated by salt solution and precipitation methods have had nitrogen values ranging up to 18.95 percent. The results indicate that the nitrogen factor for calculating protein should depend upon the method used in isolation and would range from 7.14 to 5.2.

The isolated flaxseed protein was dark and not readily dispersible in mild alkaline solutions. Further processing to improve its color and dispersing characteristics would be required to make it competitive with isolated soybean protein and casein. It is rather apparent from published results that successful production of flaxseed protein would depend upon a specialized use which would support a premium price for the extra cost of production over other available proteins.

Sunflower Seed (*Helianthus annuus* L.). World production of sunflower seed for 1951–52, exclusive of Russia, was reported as 3,300 short tons. The Soviet Union, Argentina and India are the largest producers.

Sunflower seeds have a sweet taste, and the oil is edible, light in color, and reported to be quite stable. The light color of the defatted meal suggests that the isolated protein might be nearly white.

The protein is very nutritious, accord-

ing to Mitchell and Hamilton (101) who reported a digestibility of 94.3 percent and a biological value of 64.5 from rat-feeding experiments on unheated meal. Grau and Almquist (69) reported sunflower seed protein to be " a complete single source of amino acids for the growth of young chicks, when fed to provide 20 percent protein in the diet ". Morrison, Clandinin, and Robblee (101*a*) have shown the effect of certain processing variables on the nutritive value of sunflower seed oil meal. Block and Bolling (21) have provided an amino acid analysis of the protein. The taller varieties of sunflowers have, for some years, been grown and used for ensilage in western Canada. In 1937 experimental work was started at Dominion Forage Crops Laboratory, Saskatoon, Sask., to develop and test short varieties which could be harvested with a combine for use as an oilseed crop. The initial investigations were with the Mennonite and Sunrise varieties. The raising of sunflowers for seed was started in 1943. In recent years attempts have been made in Illinois, Kansas, Montana and North Dakota to develop sunflower varieties suitable for oilseed processing. The losses from insects, diseases and birds (160) have discouraged this development in the Middle West, and production in the northernmost tier of counties of the United States has not been enough to create an active market. Yields of sunflower seeds have been about 1,000 pounds per acre so that the oil yield is approximately the same as for soybeans, while the protein yield is somewhat less.

Shewfelt and Worthington (129) have extracted a good grade of pectin from dried sunflower heads. By extracting with a mixture of equal quantities of oxalic acid and ammonium sulfate at pH 4.0, they obtained yields in the range of 14 to 18 percent. The quality and yield were markedly affected by the season, maturity and the condition of the heads.

Milner, Hubbard and Wiele (100) have determined the composition of 28 samples, comprising four varieties of sunflower seed grown at seven locations. Their results for the whole seed show a range of protein content ($N \times 6.25$) for four varieties from 18.04 percent to 21.40 percent and the oil content from 27.47 to 30.78 percent.

When the hulls, which constitute 39 to 46 percent of the seed, are removed, the protein values for the meals range from 29.4 to 32.3 percent and the oil from 46.6 to 53.2 percent; the dehulled and oil-free meal has a protein content of 60.5 to 74.25. Osborne and Campbell prepared salt-extracted proteins with nitrogen values of 18.6 percent. Smith and Johnsen (138) had salt-soluble proteins with 18.69 percent nitrogen, but their alkali-extracted and acid-precipitated protein did not exceed 17.63 percent nitrogen. These results indicate protein conversion factors of 5.4 for salt-solution soluble protein and 5.7 for alkali-acid protein.

The earliest publications on sunflower seed proteins were by Ritthausen (123) in 1880, Vines (155) in 1893, and Osborne and Campbell (109) in 1897. Osborne's protein was dark because of a substance he called " helianthotannic acid ". In more recent studies Gorter (67) identified this same compound as chlorogenic acid which has been described as a mixed didepside of caffic acid and guinic acid. Rudkin and Nelson (125) have given the structural formula for a chlorogenic acid derived from sweet potatoes and indicated its function in plants as a hydrogen carrier as determined from an oxidase system prepared from sweet potato roots. They noted that complete oxidation of the chlorogenic acid resulted in formation of a highly colored reaction mixture, and they thought the " coloration was probably due to polymerization products of hydroxyquinone ".

Smith and Johnsen (138) studied the

dispersion and precipitation, at various pH values, of the nitrogen compounds of sunflower-seed meats which had been defatted with petroleum ether or with ethanol. For the petroleum-ether-extracted meal, they found that 25 percent of the nitrogen, less than half of which is protein, dispersed in the pH range of 3.0 to 7.0, but 100 percent at pH 10.0 and above. The alcohol-extracted meal was partly denatured and more difficult to disperse. The maximum yield of protein, based on solvent-extracted and dehulled meal, was 31.8 percent. If the yield were based on defatted but undehulled meal, the yield would be much lower.

The protein which had been extracted with alkali had a dark color, mostly green, due to the presence of chlorogenic acid. Removal of the chlorogenic acid was attempted by a number of common organic solvents but without practical result. Extraction with 70 percent ethanol slowly removed the chlorogenic acid and was more effective than any other solvent tested. The presence of chlorogenic acid in the meal is indicated by a bright chrome yellow color upon addition of sodium hydroxide. The yellow color changes to green when exposed to air or oxidizing agents. At pH 9.0 the green color appeared in eight to ten minutes; at pH 11.5 the color changed directly to brown. Appearance of the green and brown colors can be prevented by use of reducing agents such as dithionite salts, but the color will gradually appear after washing out the reducing agents and exposing the protein to the air. The pH-dipersion results indicate a reaction between the protein and chlorogenic acid in the pH range of 3.0 to 7.0 to form an insoluble product. At pH 10 and above, the complex appears to be disassociated, and removal of the chlorogenic acid would be possible if a water-immiscible solvent for chlorogenic acid could be found for a liquid-liquid type of extraction at this pH value. Until some means is found for destruction or extraction of the chlorogenic acid, the sunflower-seed protein, because of its dark color, cannot compete with other industrial proteins on the market.

Soybean Seed (*Glycine max* (L.) Merrill). The soybean has been known under a variety of names, some of which have been *Phaseolus max* L., *Soja hispida* Moench, *Soja max* Piper and *Glycine soja* Siebold and Zuc. Ricker and Morse (121) have recently concluded that the only acceptable name under the rules of the International Botanical Congress is *Glycine max* (L.) Merrill.

There are numerous varieties of soybeans which vary widely in chemical composition. Piper and Morse (115) state that practically every locality in China and Manchuria has its own type or variety. Cartter and Hopper (33) reported that by 1942 more than ten thousand introductions had been brought to this country, mainly from the Orient, for examination of their suitability for production here. The varieties differ widely in color of seed, size of bean, climatic conditions necessary for satisfactory growth and production, and in chemical analysis. An average analysis on a moisture-free basis would be 40 percent protein, 20 percent oil, eight percent sugar calculated as sucrose, and 5 percent ash.

During and immediately after the war years, the shortage of vegetable oil and its resulting high price played an important part in the rapid increase in soybean production. With the return to normal oil supplies throughout the world, the price of oil has declined and our country is presently faced with a substantial surplus. Soybean oil meal (44 percent protein), which makes up about 60 percent of the value of the processed materials (meal, oil and phosphatide), has never been classified as surplus. Soybean oil meal is our most important protein concentrate, and the great demand for a low-cost protein in the pro-

duction of high-priced meat is an important factor in keeping it from becoming a surplus product.

Interest in soybeans as a farm crop developed rapidly in the Middle West, especially in central Illinois during the 1930's. Their culture is profitable in the same general area as corn. The ease of growing, harvesting and processing soybeans for oil and meal gives them an advantage over other oilseed crops in the economy of production of oil and of protein concentrates. Cost of production in labor has been reported as ranging from seven to ten man-minutes per bushel. The annual production of about 300 million bushels assures an unlimited source of supply of raw material for protein isolation.

Soybean protein is the only industrial protein isolated from oilseeds in the United States. The research investigations reported above indicate that development of a competitive oilseed protein isolate is rather remote. Soybean protein has several advantages over other oilseed proteins in that it is obtained in a higher yield and has a better color; also, its present state of production and development for many special applications has given it a head start which will be difficult to overcome by other oilseed proteins.

The first known publication on soybean protein is that of Meissl and Böcker (98) in 1883. However, the work of Osborne and Campbell (110) in 1898 has been the most popular literature reference. The primary interest of the early investigators was identification of various specific proteins by salt-solution methods of separation. As early as 1921 Sadakichi Satow (126) conducted extensive investigations on the isolation and utilization of soybean protein, and, although his investigations were only semiquantitative, they contain much useful information.

Smith, Circle and Brother (137) and others (102, 135) has shown that about 92 percent of the protein of oil-free soybean meal can be extracted with distilled water. The pH of such solutions is usually 6.6. Contrary to the behavior of most vegetable proteins, low concentrations of neutral salts reduce the dispersion of the protein. For example, 0.1 N sodium chloride in water lowers dispersion from 92 to 45 percent, and 0.0175 N calcium or magnesium chloride lowers the dispersion of nitrogen components to 21 percent. This cation effect is overcome by increasing the concentration of the salt or by raising the pH of the system (136).

Briggs and Mann (27) were the first to investigate soybean protein solutions by means of electrophoretic patterns. Their work reveals at least seven different protein fractions in a water extract of defatted soy flour when dispersed in a phosphate buffer at pH 7.6. They found that about 75 percent of the total protein migrated as a fraction, which they identified as a mixture of at least three components. No truly homogeneous proteins were isolated.

Figure 2 shows the dispersion of the nitrogenous constituents of oil-free soybean meal at various pH values with several different acids and bases. To obtain high yield of protein the meal is extracted by adding water and adjusting to about pH 9.0. The insoluble residue is removed in a centrifuge and the protein precipitated with acid in the pH range of 4.6–4.1. The acid precipitation curve is almost exactly the reverse of the extraction curve of Figure 2. The protein isolated by this procedure is a mixture of globulins and glutelins, and in laboratory-scale operation as much as 84 percent of the total protein of the meal is recovered. Thus, if dehulled, oil-free meal containing 50 percent protein is used, the yield would be 42 percent. However, in large-scale processing the yields will be much lower, partly due to the lower water to meal ratio which must be used in commercial operations. A

yield of 30 percent would be considered good.

The solubles in the filtrate from the wet protein curd contain albumin, proteoses, peptones, nonprotein nitrogen, sugars, trypsin inhibitor, urease, lipoxidase, other enzymes and water-soluble components of the bean. This solution, with its many interesting components, is called " soybean whey ", and constitutes about one-third of the original meal. Although several components of the whey have potential value, economic methods for their recovery have not yet been developed. The whey has a very high biological oxygen demand, and its disposal is a serious problem for some soy-protein processors.

While the isolation of small quantities of protein in the laboratory is a simple operation, translation of the process to commercial scale presents many engineering problems. Belter, Beckel and Smith (18) have described a pilot plant which demonstrates the equipment and problems of large-scale production. The first difficulty encountered in the operation is separating the protein solution from the residue. This separation cannot be effected by filtration. Therefore the coarse residue is removed by an 80-mesh screen and the remaining fines in a continuous centrifuge. The acid-precipitated protein is settled and the curd filtered on a string type filter. The protein curd is approximately 75 percent water and must be carefully dried to prevent heat degradation.

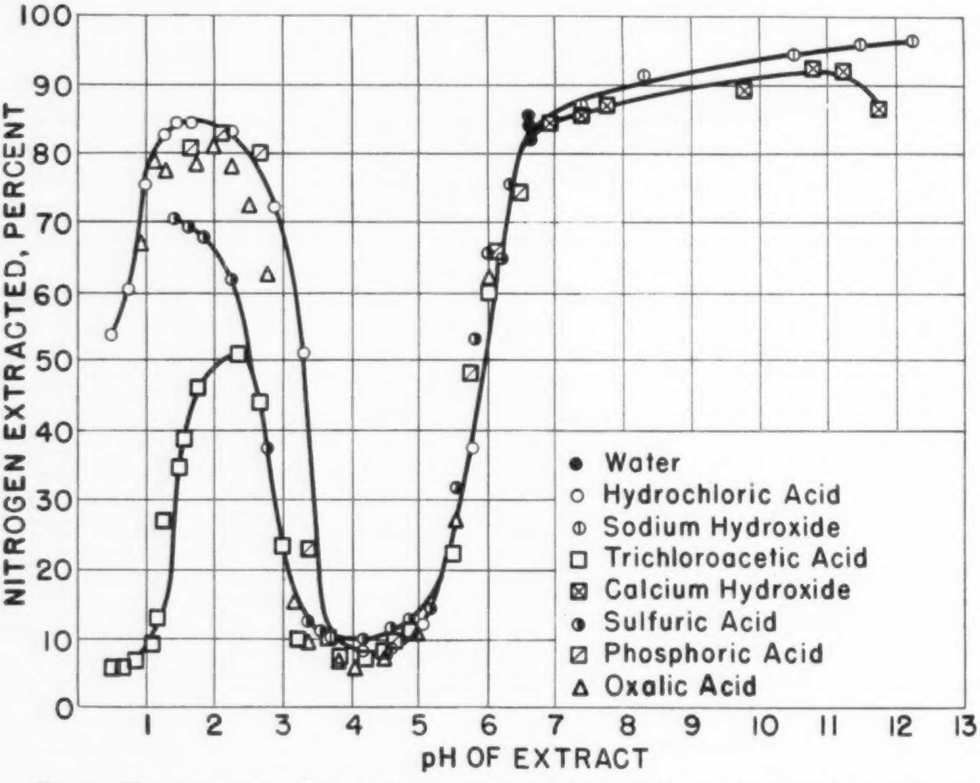

FIG. 2. The percentage of total nitrogen extracted from oil-free soybean meal by acids and bases.

Sodium sulfite may be used in the extraction process to reduce the activity of microorganisms and to assist in bleaching the protein. Further bleaching is accomplished by precipitation of the protein curd with sulfur dioxide. Powerful but more expensive bleaches (141) are sodium dithionite ($Na_2S_2O_4$), zinc dithionite (ZnS_2O_4) and peroxides. The protein is bleached to a color equivalent in brightness to casein.

A survey of the industrial uses of soybean meal, isolated protein, soy flour, zein, corn gluten and other protein concentrates was made by Arthur D. Little, Inc., under the supervision of the Bureaus of Agricultural Economics and Agricultural and Industrial Chemistry, and was published as USDA Tech. Bull. No. 1043 in September, 1951 (97). According to the survey, the principal uses for isolated soybean protein were pigment coating of paper, wallpaper coating, water and latex paints, lamination of fiber board and shotgun-shell tubes, fire-foam liquid, printing inks, leather finishing, felt-base floor covering, and other formulations for sizing and adhesive applications. Total annual industrial utilization at that time was estimated at 27 million pounds, with pigment coating of paper accounting for more than half of the production. Present production data for soybean protein are still not available. However, the trend of isolated protein utilization since 1951 has been reported as increasing so that present production should be substantially above the 1951 estimate.

The largest potential use of soybean protein is for textile fibers, but this use has not yet been developed. Fibers comparable to the casein fiber, Aralac, which was produced during World War II, have been made experimentally by the Ford Motor Company (1937), The Drackett Company (1940) and the U. S. Department of Agriculture (1942). The greatest weakness of Aralac was its wet strength, and commercial production did not prove feasible. The Japanese, who were experimenting with soybean fibers before the war, have resumed their research. The British development of a commercial fiber from peanut protein, and the American development of a fiber from zein support the belief that a successful fiber can be made from soybean protein. Such a development might very well double the present rate of soybean protein production.

Soybean meal, when dehulled, analyzes about 50 percent protein and has several industrial uses which, on a tonnage basis, far exceed the utilization of the isolated protein. These uses are for plywood glue, wallpaper coating, and adhesive formulations for the manufacture of paper products. The 1951 survey (97) gave the industrial utilization of the meal as 51.5 million pounds. The largest single use for the meal, for plywood glue in the Douglas fir plywood industry, amounted in 1951 to 35 million pounds. Recent reports indicate this application has increased to 60 million pounds, thus showing a decided upward trend in the industrial utilization of the meal. Chang (37) has described a new use for soy flour, as a sugar liquor defecant in the sugar-refining industry. This application has the advantage that the soy flour is recovered and sold as stock feed.

A new product known as Gelsoy (15), which was developed for food uses, also has heat-sealing properties which recommend it for use in sealing the cork into crown seals as well as other special adhesive applications. The insoluble portion of the soybean meal has been shown to be an acceptable extender for phenolic resin plywood glues (10).

Castor Beans (*Ricinus Communis* L.). The castor-bean plant, also called "palma christi", is a member of the Euphorbiaceae family and is not a legume or true bean as believed by many.

Indigenous to Africa and India, it is now grown to some extent in many countries. In tropical zones it is a perennial that may reach heights of 30 to 40 feet and bear fruit for more than 20 years. However, in temperate zones it is an annual with commercial varieties having a height of three to ten feet. It is frequently grown for ornamental purposes.

The commercial interest in castor beans is due to the unusual properties of its oil. The special properties of the oil are the result of its high content of ricinoleic acid which makes up 91.4 to 94.9 percent of its total fatty acids (70). Ricinoleic acid is the only fatty acid found in our commercial oils which contains a hydroxyl group, giving to castor oil the unusual property of greater solubility in ethanol than in hydrocarbon solvents.

Castor oil has many specialized uses (159) such as a lubricant for airplane engines, airplane landing gear, gun carriages and bomb-bay doors, and as a component of hydraulic brake fluids, varnishes, flypaper, soap, cosmetics and flexible coatings. In its dehydrated form it is used in combination with soybean oil in paints and other drying-oil systems.

World production of castor beans is probably in excess of 500 thousand tons. Castors have been produced in the United States in varying but limited quantities since 1800. In 1900 production was reported as zero. The present annual need for industrial purposes is about 350 million pounds of beans or its equivalent of 125 million pounds of oil. Because of the strategic nature of the oil, production in the United States has been encouraged by the Munitions Board through contract arrangements with a private company, so that production goals for 1952 were set at 200 thousand acres for over 100 million pounds of beans.

Expansion of castor-bean production to self-sufficiency for this country has been held back because the types of castor plants normally grown were not suitable for mechanical harvesting and hulling. As in other countries, harvesting has always been by hand. Therefore the varieties selected for growth were those that spontaneously shattered their beans from the spikes on maturity. Such varieties are not suitable for mechanical harvesting. The development of new varieties and equipment for harvesting and hulling has been described by Domingo (49) and others (150, 151, 128, 120, 36). These developments have been progressing successfully since 1940, so that it now appears that the United States will soon be able to grow its own requirements of castor beans on an economically sound basis.

Castor-bean seeds weigh 0.13–0.74 gm., and contain 45 to 50 percent oil. The hull comprises 18 to 22 percent of the seed, and the kernel 78 to 82 percent (70). Following is an analysis of the whole seed, kernel and hulls (72):

	Composition of seed	Moisture	Protein	Oil	Carbohydrate	Fiber	Ash
	%	%	%	%	%	%	%
Whole seed	..	5.14	17.88	46.65	12.61	14.99	2.73
Kernel	70	3.60	23.43	66.02	4.01	0.70	2.24
Hull	30	8.76	4.76	0.98	32.92	48.69	3.89

The light-colored, oil-free meal from decorticated seed contains 45 to 50 percent protein. Use of this protein or meal has been limited to fertilizer because of the toxicity factor present which is difficult to destroy.

The principal proteins of the castor

bean are globulins. However, the proteins of greatest interest are the extremely toxic ricin and the allergens. T. Dixon in 1886 (48) was the first to indicate that the toxic principle in the castor bean is a protein, and Stillmark is given credit for naming it "ricin" in 1888 (145).

Osborne, Mendel and Harris (111, 107) isolated a ricin fraction and studied its hemagglutinating and toxic properties. They also indicated their reasons for calling it an albumin, and found that, when subcutaneously injected, 0.0005 mg. per kilogram of body weight was fatal to rabbits. More recently Kabat, Heidelberger and Bezer (87) and Kunitz and McDonald (92) have crystallized and separated toxic and nontoxic forms of ricin and studied their properties. They described their ricin as a globulin, although solubility tests indicated the presence of more than one protein component in their crystalline material, possibly in the form of a solid solution. Kunitz and McDonald determined the isoelectric point of ricin as pH 5.4 to 5.5 and, assuming spherical particles, its molecular weight as 26,000. According to Kabat et al, the isoelectric point is 5.2 to 5.5 and the molecular weight is 77,000 to 85,000 for an assumed specific volume of 0.75.

Another serious problem connected with commercialization of castor-bean meal or protein is the hazard of developing allergies by those associated with the work. Spies, Coulson, Stevens and associates (134, 133) at the Allergens Investigations Laboratory in the U. S. Department of Agriculture have found that castor bean contains a relatively high concentration of allergens. These potent allergens have an unusual sensitizing capacity in human subjects exposed to inhalation of the dust from the pomace, according to reports emanating from areas where castor beans are processed (85). The powerful activity of the castor-bean allergens is difficult to destroy because of their remarkable stability toward heat and chemicals. They are reported to be unaffected by prolonged boiling in water.

Kodras, Whitehair and MacVicar (91) investigated the detoxification of castor-seed pomace and stated that autoclaving for 15 minutes at 125° C. produced essentially complete destruction of ricin with minimal changes in the physical character of the pomace. The resulting meal did not have a high biological value. They did not indicate the extent of desruction of the allergens by their autoclaving.

Amino acid analysis of the protein shows 20 percent glutamic acid, indicating a possible utilization of castor bean protein as a raw material for production of monosodium glutamate.

However, until some new methods for handling and processing castor-bean meal are developed, which will protect the workers from sensitization by the allergens, there is not much chance that it will be used as a source of isolated protein or find use other than as a fertilizer.

Seed of Peanuts (*Arachis hypogaea* L.). On a world-wide basis, peanuts are the second largest oilseed crop. They are grown widely in tropical and subtropical areas, and are known by many names, among which are "ground nut", "goober", "monkey nut", "manilla nut" and "pindars". It was long believed that the peanut was indigenous to Africa and India. However, it is now known to be native to South America. Peanuts were grown by the South American Indians who placed funerary jars containing them in tombs of the dead; jars found in a prehistoric cemetery near Lima were decorated with replicas of peanut pods sculptured in relief, indicating the esteem in which peanuts were held by these people (161).

World production is about ten million

tons, and the leading producing countries are India, China, United States, Africa and Brazil. Annual production in the United States has been nearly one million tons for the last ten years. The comparatively high level of production in the U. S. is maintained through a government price support program, and the resulting high price restricts their principal use to edible products—peanut butter, whole nuts and confections (12). Only peanuts of low quality or those under a subsidized program are crushed for oil (11, 149). Peanuts are remarkable for their concentrated food value of 5.8 calories per gram which is slightly more than 2.5 times that for an equal quantity of beefsteak.

The principal strains of peanuts are Virginia, Spanish and Runners. They are grown primarily in Virginia, North Carolina, South Carolina, Georgia, Alabama, Mississippi and Texas. Their cultivation, breeding and differentiating characteristics have been described in an Experiment Station bulletin (75) and a USDA bulletin (13). Lieberherr (93) has published a pamphlet on ground nuts in India.

Because of the shortage of vegetable oils and protein concentrates in the United Kingdom and because the traditional supply of peanut oil from India was no longer available, the United African Company, Ltd., in cooperation with the British Government, undertook in 1946, but without preliminary experimental testing, a large-scale development of ground nuts in Tanganyika, British East Africa. At one time, at an estimated expense of 67 million dollars, this project called for clearing and planting as much as 3,210 thousand acres of ground nuts, using power equipment (1). The project was carried on for several years, but in recent reports it was indicated that the climate and soil of this area are not suitable for peanut culture. In 1950 the British Food Minister announced in the House of Commons that attempts to produce large quantities of peanut oil and peanut meal would be given up, and the project turned into a colonial development with a diversified crop program.

The unusual harvesting method for peanuts is a considerable factor in their high cost of production. The peanut matures beneath the surface of the ground, and in harvesting it is ploughed out, the dirt removed, and the whole vines are shocked by hand, and placed on poles with cross pieces near the top, for curing. After a few weeks they can be shelled and the vines used for feed. If the character of the peanut plant permitted harvesting with a combine as for soybean, there is little doubt that their present production in this country would be on a much larger scale and their economic position would be on a firmer basis. Research on the development of combines for harvesting and drying peanuts is now under way (130).

The cellulosic shell comprises 20 to 30 percent of the weight of the whole peanut. The seed contains 45 to 50 percent oil, 25 to 30 percent protein, 5 to 12 percent carbohydrate, 2.5 percent ash, and about 3.0 percent crude fiber (71). Thus the oil-free meal contains about 50 percent protein. Hoffpauir (76) has recently published a review of the literature on peanut composition.

Johns and Jones (81), by salt solution and precipitation methods, isolated and named the two major peanut protein components, arachin and conarachin. Arachin was prepared by extracting the oil-free meal with ten percent sodium chloride solution, followed by precipitation with 0.2 saturated solution of ammonium sulfate. The filtrate from the arachin precipitation was then saturated eight-tenths with ammonium sulfate to give conarachin. The isoelectric points of arachin and conarachin have been reported in the pH ranges of 5.1 to 5.2 and

3.9 to 4.0, respectively. Eirich and Rideal (53), using an air-driven top centrifuge of the Beans-McBain type, identified five protein fractions in arachin having molecular weights of 20,000, 30,000 140,000, 400,000 and 600,000.

Irving, Fontaine and Warner (80) made an electrophoretic investigation of an extract containing about 98 percent of the total protein of the peanut and found two major and two minor fractions. The two major components comprised about 87 percent of the total protein which occurred in the approximate ratio of seven to one. The two remaining proteins comprised about 13 percent of the total protein and were present in about equal amounts. Also, according to their results, arachin accounts for approximately 63 percent of the total protein of the peanut and is made up of the two major electrophoretic components in the ratio of three to one. The conarachin comprises 33 percent of the protein and consists of one major electrophoretic component and two minor components.

In ultracentrifugal measurements, Johnson and others (82, 83, 84, 66) have shown that when arachin is salted out of a saline solution with ammonium sulfate it consists of one sedimenting species having a constant of S°_{20} 14.6. However, when precipitated by dilution and adjustment to pH 5.0 it consists of two sedimenting species having constants of S°_{20} 14.6 and 9.5. If these two species are dissolved in sodium chloride and reprecipitated with ammonium sulfate, a globulin consisting of one sedimenting species with S°_{20} 14.6 is again obtained. From these and other results they have concluded that arachin under certain conditions is dissociable into two molecular species. Johnson and Shooter (84) have concluded that a low salt concentration and a pH of about 5.0 are essential to dissociate the arachin S°_{20} 14.6. Assuming spherical shape and specific volume of 0.72, Johnson (83) found, by his ultracentrifugal measurements, for the S°_{20} 14.6 and S°_{20} 9.5 molecular weights of 250,000 and 130,000, respectively. He also found two smaller fractions with molecular weights of 68,000 and 47,000. Light-scattering methods (66) gave a molecular weight for arachin of 542,000.

Fontaine and Burnett (59, 29) and others (63) have determined the variation of nitrogen dispersion of oil-free peanut meal with pH changes, and their results are remarkably similar to results for soybean meal shown in Figure 2. Their data show that about 90 percent of the peanut-meal nitrogen can be extracted with water at a pH of about 6.7, whereas the minimum extraction of about 7.7 percent occurs at pH 4.3. Pilot-plant studies have been made which have demonstrated equipment and methods to be followed for the commercial production of isolated peanut protein (4, 118). Processing variables in peanut-protein preparation (117) have been studied.

The redskins (testa) comprise 2.0 to 3.5 percent of the peanut kernels and contain tannins and related pigments (60, 143, 144) which, unless removed early in processing, seriously darken the color of the protein.

Possible utilization of the protein for plywood glue (30, 31, 32, 77), paper coatings (7), window-shade sizes (3), textile fibers (6) and similar uses (2) has been demonstrated. Jett C. Arthur has recently reviewed in detail the literature on isolation and industrial utilization of peanut protein (1*a*).

At present there is no commercial production of peanut protein in this country. Research at the Southern Utilization Research Branch, New Orleans, however, has developed suitable methods for large-scale isolation and has indicated that the protein can be adapted to many industrial applications. If the

present trends of the industry toward mechanical harvesting of peanuts and solvent extraction of the oil are successful, peanuts will attain a better economic position as an oilseed crop in this country, and production of isolated protein will be a feasible undertaking.

The economic situation regarding peanuts and peanut protein for Great Britain is better than for the United States. It was recently reported that the British Extracting Company in Bromborough, England, is now turning out 100 tons of solvent-extracted peanut meal per day and that the Imperial Chemicals Industries isolates the protein at a capacity of ten tons per day and converts it to a textile fiber known as Ardil at a plant in Dunfries, Scotland. It is further reported that they soon expect to double this rate of textile fiber production.

Seed of Cotton (*Gossypium* sp. L.). Cottonseed oil meal is second only to soybean oil meal in tonnage production. The cottonseed industry, until recently, has depended on hydraulic and screw presses for removal of the oil; however, as a result of recent researches, the present trend is toward solvent extraction. The meal or cake from the extraction processes has been successfully used for many years in feeds for ruminants, but its use has been limited as a feed for poultry, swine and other nonruminants because of the presence of antinutritional components.

Nutritional investigations carried out by the Southern Utilization Branch (23, 51, 99, 146) in collaboration with industry and various State experiment stations on cottonseed fractions have demonstrated rather conclusively that the pigment glands contain the antinutritional factor or factors of the cottonseed. Boatner et al. (24, 22, 119) have shown the glands make up from 2.37 to 4.81 percent of the cottonseed, and that the principal pigments in the glands are gossypol and gossypurpin. After separation of the glands from cottonseed meal and analysis of the pigments by light absorption methods, they found the glands to contain by weight 39 to 50 percent gossypol and 0.612 to 1.73 percent gossypurpin.

Cooking cottonseed in the presence of moisture, as in preparation for hydraulic or screw-press operation (26), has several important effects on the system, especially on the pigment glands which swell and break open. At the same time cooking destroys most of the toxic principle contained in the glands. The present trend in the industry is to cook the meats at about 200° F. while at a high moisture level (12–15 percent) and to remove 50 percent or more of the oil in a screw press prior to solvent extraction (49*a*).

It has been shown in solvent-extraction studies that the oil can be removed by using dry organic solvents without seriously disturbing the glands, whereas in using organic solvents (25, 26), such as alcohols and acetone containing some water, the glands swell and break open, thus permitting extraction of both the oil and pigments. The glands can also be removed successfully on a small scale by mechanical means (157, 131, 156). Nutritional studies have demonstrated that reduction of the gossypol to 0.03 percent or less effectively relieves the toxic effect of cottonseed meal.

In poultry feeding (74), for example, it was shown that gossypol had an appreciable adverse effect on hatchability and egg weight when mixed with the diet at the 0.024-percent level and a still greater adverse effect at the 0.036-percent level, but did not affect either hatchability or egg weight at the 0.012-percent level. Lyman et al. (94) also have demonstrated adverse nutritional effects due to gossypol.

Experiments with goldfish and with mice (34, 35) have indicated that the

toxic effects of pigment glands are due to a reaction product of gossypol with other components of the meal, not to the gossypol alone. Eagle and others (52, 50) have produced similar results with rats showing that mortality and body weight effects on the rats caused by adding pigment glands of cottonseed at various levels to the diet cannot be attributed to the gossypol content alone. One of the toxic combinations was found to be gossypol with dextrose (35).

The extensive investigations on the adverse effects of cottonseed pigments and of their reaction products on animal nutrition led to a number of pilot-plant studies (132, 114) on methods for removing the pigments from the meal. The results of these studies have made possible the present trend of converting the industry to solvent extraction, and have led to reduction of the gossypol or other toxic components to a safe level. The developments of commercial methods for removing the pigments from cottonseed for greater feed efficiency have also been an important contribution to studies on isolated protein and to its industrial utilization. Removal of the pigments is a valuable contribution toward the development of a light-colored protein which is essential for many applications.

Work on cottonseed protein always starts with dehulled seed or meats. The solvent-extracted meats, on a moisture-free basis, contain about 9.5 percent nitrogen or 52 percent protein ($N \times 5.55$), 8.25 percent ash, and 0.5 to 2.0 percent lipids.

The early investigators of cottonseed protein were Osborne and Vorhees (112) and Jones and Csonka (86). In their studies with salt solutions, dilute ethyl alcohol, and sodium hydroxide, they fractionated the protein into high-ash-yielding fractions I and II, a pentose protein, a glutelin, and α- and β-globulins. They believed the high-ash-yielding fractions to be phosphoproteins. More recent work by Fontaine, Pons and Irving (62) indicates the high ash may be due to phytin.

Olcott and Fontaine (104, 105, 106, 61) investigated the dispersion of the protein of cottonseed meats by a large variety of salts, by pH variation, and by the superimposed effect of salts on pH variation. They found many salts which, at 1.0 *N* concentration, would disperse 80 percent or more of the nitrogen.

In studies on the nitrogen dispersion as a function of pH they found it necessary to raise the alkalinity above pH 8.5 to attain good dispersion values. At pH 9.0 the amount of nitrogen dispersed was markedly affected by the presence of salts. For example, calcium and magnesium salts, in the concentration range of 0.03 to 0.05 *N*, completely suppress dispersion of the globulins. This behavior, it is pointed out, corresponds to the action of salts on soybean protein, as demonstrated by Smith et al. (137), except that the cationic effect of soybean proteins was at about pH 6.6.

Electrophoretic studies (88) have been made to determine the effect of type and pH of buffers, the effect of the solvent used to extract the protein from the meal, and the effect of temperature (89) between 0° and 20° C. on the relative concentration and the mobility of the protein components. The results of these studies showed that the whole meal contained two major and two minor components. It was also shown that fractions of the two major components could be obtained in a purified form by dialyzing a salt solution extract of the meal against selected concentrations of sodium chloride.

Different methods of removing the oil and of extracting the protein from the meal have been studied (8, 38, 9, 116) to determine the effect of such modifying treatments on the viscosity, yield and other properties of the protein pertaining to industrial processing and utiliza-

tion. Methods for the production of cottonseed protein fibers (5) and glues (78) have been developed, and the present limitations of these methods have been demonstrated.

At present there is no commercial production of isolated cottonseed protein, but the considerable research that has been completed to date in developing a solvent extracted meal low in pigments make cottonseed meal a potential source of industrial protein.

Continued research and improvement in the solvent extraction of cottonseed could be expected to develop a quality of product competitive with soybean meal as a source of isolated protein.

Corn (*Zea Mays* L.). Corn is our largest and most valuable agricultural grain crop with an annual production in recent years of over three billion bushels. Corn is composed of 6.5 to 20 percent protein (average about 11 percent), 5.5 percent oil, 70 percent starch, and 1.5 percent ash. About 95 million bushels of corn or three percent of production is processed by the dry corn milling industry into breakfast foods, cornmeal, flour, hominy grits, and flakes for human food and fermented malt liquors. Another 130 million bushels or about four percent is processed into starch, germ and gluten. Much of the starch is converted into dextrin adhesives, corn sugar and glucose syrups. The germ, which is easily separated from the endosperm by a flotation process, constitutes about 12 percent of the kernel, is 35 percent oil and 19 percent protein. The oil is recovered by means of screw presses or by solvent extraction, and finds a good market as a salad oil and for other food uses. The proteins of the germ meal have an excellent balance of essential amino acids, giving them a nutritional value equivalent to some of the meat proteins, although at present it is used only in feed formulations.

Corn endosperm is about 11.5 percent protein, 86 percent starch, 0.85 percent oil, and 0.3 percent ash. In processing the endosperm the starch is separated from the corn gluten by gravity methods using centrifuges or settling as it moves slowly over long tables. The impure gluten normally contains about 50 percent protein, although by special destarching processes with enzyme or acid hydrolysis, the protein can be increased to 70 percent. A mixture of the gluten and extracted germ is referred to as " gluten meal " and " feed ", and is used in the preparation of mixed animal feeds, although at least one processor is using the gluten as a source of monosodium glutamate.

The gluten is rich in an alcohol-soluble (70 to 90 percent) protein known as " zein ", the only protein isolated from a cereal gran for industrial uses. Zein belongs to a class of proteins known as " prolamines " which are the best characterized of the several classes of proteins, not only because of their distinctive solubility in aqueous alcohol solution and other organic solvents (57, 95, 96, 56) but also because of their characteristic chemical composition which, on hydrolysis, is shown to be high in proline and amide nitrogen with essentially no lysine. Zein was first isolated and named by Graham (65) in 1821. Between 1891 and 1920 Osborne and associates (107) published more on corn proteins than they did on any other vegetable protein. Research in recent years, which led in 1938 to the commercial isolation of zein and to the development of a number of industrial utilizations, has been done by the larger processors of corn and by the Northern Utilization Branch.

The zein content of corn varies from one to eight percent (73) and is in linear relationship to the total protein. However, for practical purposes, it is usually stated that the potential yield of zein is one pound per bushel of corn. While

present production data for zein are unavailable, it is probable that no more than five percent of the potential production is realized.

Swallen (147) has given the most recent description of the procedure for commercial isolation of zein. The corn gluten, containing 50 to 55 percent protein, of which about 70 percent would be classified as zein, is extracted countercurrently with 85 percent isopropanol at about 60° C. The alcohol extract contains about six grams of protein per 100 ml. as well as practically all of the oil, the xanthophyll pigments and some of the water-soluble components. The extract is cooled to 15° C. to precipitate undesirable components, filtered, and mixed with 80 to 120 parts of hexane by volume. The hexane dissolves the oil, xanthophyll pigments and much of the isopropanol so that on separating the two solvents in a centrifuge, the heavier layer consists of 15 to 20 percent zein in about 60 percent isopropanol solution. The zein is precipitated by spraying the isopropanol solution into refrigerated water. The precipitate is recovered by filtering and is then mixed with previously dried zein for flash drying. Evans et al. (55) described a laboratory method for preparing zein which resembles the commercial method except that it is on a smaller scale.

In terms of physical chemical constants, zein is not specifically defined. Cohn, Berggren and Hendry (41, 42), by investigation of the distribution of amino acids present, found a possible molecular weight of 40,000 on the assumption that only one molecule of histidine is present in a molecule of zein. Watson, Arrhenius and Williams (158) fractionated zein by adding successive amounts of water to a zein solution in 70 percent alcohol and by sedimentation methods found the major fraction to have a molecular weight of 35,000 and the other fractions to be lower. Using an isoelectric method, they noted the isoelectric point to range between 5 and 6; the main component had an isoelectric point of 5.6.

Gortner and MacDonald (68) fractionated zein from methyl cellosolve by addition of water. By osmotic pressure methods, they found fractions ranging in molecular weight from 23,330 to 45,030; their fractions also had a range of nitrogen values from 12.98 to 15.77. This variation in nitrogen need not be significant as it could be due to impurities.

Scallet (127) studied the association-dissociation of zein components as affected by dilution of buffer solutions and pH of the solution. He concluded that zein solutions contain at least six components of different electrophoretic mobility which constitute a reversible association-dissociation system. The equilibrium between the components is easily disturbed by changes in protein concentration, buffer concentration or pH of the solution. He concludes that it is not possible to clearly separate the components by fractional precipitation from solutions of ordinary concentrations, but they can be separated in the Tiselius electrophoretic apparatus.

Many uses of zein are dependent on its solubility in volatile organic solvents. These and other outlets include spirit varnish formulations (mixed with rosin) for replacement of shellac, special decorative and greaseproof coatings, printing inks, cork binder, special adhesive application and textile fibers. Zein has entered also into the making of excellent phonograph records. Research at the Northern Utilization Branch culminated in 1948 in the commercialization of a zein fiber by a wet-spinning method which accounts for practically all of the present production. The development of a textile fiber (45) by a wet-spinning method depended upon earlier work which defined the limitations for the dis-

persion of zein in aqueous alkaline solutions (142, 103). Zein is completely dispersed in aqueous sodium and potassium hydroxide solutions in a pH range of 11.3 to 12.7, but the dispersibility falls to nearly zero immediately outside this range. However, zein is insoluble in calcium and ammonium hydroxide solutions. Methods for stabilizing fiber (54, 44, 43) and a comparison of its physical properties with wool and synthetic fibers have been published (47). Zein fibers are marketed under the trade name Vicara and resemble wool more than any other textile fiber.

Trail (148) has briefly reviewed the chemistry and history of regenerated protein fibers from soybean and peanut proteins, zein, casein, gelatin, egg white and chicken feathers. He compared their properties with wool, silk, cotton and several of the synthetic fibers. Trail says " it would be unwise to predict the future of these regenerated protein fibers. A great impetus has been given to all manufactured fibers by the unprecedented rise in the prices of wool and cotton. The increase in the population of the world and more important, the increase in the standard of living, have created a demand for textile fibers which has been met only through the introduction of manufactured fibers into our everyday life ".

Although none of the presently manufactured synthetic fibers has the properties of wool, they have replaced or supplemented silk and cotton. Much research is now in progress toward the development of a synthetic fiber capable of replacing wool. On the other hand the research on regenerated protein fiber in this country has been practically discontinued so that present trends indicate that our shortage of wool will eventually be supplied by the development of a synthetic fiber rather than by a regenerated protein fiber.

Literature Cited

1. Angelidis, Alex. Britain ends African peanut scheme. For. Agr. **15:** 106–108. 1951.

1a. Arthur, Jett C. Peanut protein—isolation, composition, and properties. Adv. Prot. Chem. Vol. 8, Chap. 6. 1953.

2. ———. Evaluation of peanut protein for industrial utilization. A review. Jour. Am. Oil Chem. Soc. **26:** 668–671. 1949.

3. ——— and Cheng, F. W. Peanut protein for window shade sizes. Am. Dyestuff Rep. **38:** 535–537. 1949.

4. ———, Crovetto, A. J., Molaison, L. J., Guilbeau, W. F., and Altschul, A. M. Pilot-plant manufacture of peanut protein. Jour. Am. Oil Chem. Soc. **25:** 398–400. 1948.

5. ——— and Many, Hugh G. Cottonseed protein fiber. Textile Res. **19:** 605–608. 1949.

6. ——— and ———. Peanut protein fiber—pilot plant scale. Am. Dyestuff Rep. **39:** 719–722. 1950.

7. ———, Mason, T. W., and Adams, Mabelle. Peanut protein paper coatings. Jour. Am. Oil Chem. Soc. **25:** 338–340. 1948.

8. ——— and Karon, Melvin K. Preparation and properties of cottonseed protein dispersions. *Ibid.* **25:** 99–102. 1948.

9. ——— and Saik, Barbara H. Intrinsic viscosity of cottonseed globulin solutions. Jour. Colloid. Sci. **5:** 326–330. 1950.

10. Babcock, Glen E., and Smith, Allan K. Extending phenolic resin plywood glues with proteinaceous materials. Ind. & Eng. Chem. **39:** 85–88. 1947.

11. Bachman, K. L., Crowe, G. B., and Goodman, K. V. Peanuts and southern agriculture. U. S. Dept. Agr., Bur. Agr. Econ. 112 pp. 1947.

12. Banna, Antoine, Armore, Sidney J., and Foot, Richard J. Peanuts and their uses for food. U. S. Dept. Agr., Bur. Agr. Econ., Market. Res. Rep. 16. 1952. [50–75% of the peanuts are used for food].

13. Beattie, W. R., and Beattie, J. H. Peanut growing. U. S. Dept. Agr., Farm. Bull. 1656. Rev. March, 1943.

14. Beckel, A. C. A bibliography on the solvent extraction of vegetable oils from raw materials, with special attention to soybeans. Oil & Soap **21:** 264–270. 1944.

15. ———, Belter, P. A., and Smith, A. K. A new soybean product, Gelsoy. Soybean Dig. **10:** 17–18, 40. 1949.

16. ———, Bull, W. C., and Hopper, T. H. Heat denaturation of the protein in soybean meal. Ind. & Eng. Chem. **34:** 973–976. 1942.
17. ——— and ———. Moisture content of soybean oil meals. *Ibid.* **33:** 1448–1452. 1941.
18. Belter, P. A., Beckel, A. C., and Smith, A. K. Soybean protein production. Comparison of the use of alcohol extracted with petroleum ether-extracted flakes in a pilot plant. *Ibid.* **36:** 799–803. 1944.
19. ———, Brekke, O. L., and Smith, A. K. Flash desolventizer. Jour. Am. Oil Chem. Soc. **31:** 401–403. 1954.
20. ——— and Smith, Allan K. Protein denaturation in soybean meal during processing. *Ibid.* **29:** 170–174. 1952.
21. Block, R. J., and Bolling, Diana. A note on the amino acid yielded by yeast, sunflower seed meal, and sesame seed after hydrolysis of the fat free tissue. Arch. Biochem. **6:** 277–279. 1945.
22. Boatner, C. H., Hall, C. M., O'Connor, R. T., and Castillon, L. E. Pigment glands of cottonseed. III. Distribution and some properties of cottonseed pigments. Bot. Gaz. **109:** 108–120. 1947.
23. ———, Altschul, A. M., Irving, G. W., Jr., Pollard, E. F., and Schaefer, H. C. The nutritive value of cottonseed for chicks as affected by methods of processing and content of pigment glands. Poul. Sci. **27**(3): 315–327. 1948.
24. ———, Caravella, Maizie, and Kayme, Lillian. Quantitative determination of extractable gossypol in cottonseed and cottonseed meal. Ind. & Eng. Chem. **16:** 566–572. 1944.
25. ——— and Hall, C. M. The pigment glands of cottonseed. I. Behavior of the glands toward organic solvents. Oil & Soap **23:** 123–128. 1946.
26. ———, Hall, C. M., O'Connor, R. T., Castillon, L. E., and Curet, M. C. Processing of cottonseed. I. Pigment distribution in oils and meals produced by hydraulic and screw press methods. Jour. Am. Oil Chem. Soc. **24:** 97–106. 1947. II. Factors determining the distribution and properties of pigments in products prepared by solvent extraction. *Ibid.* **24:** 276–283. 1947.
27. Boulter, G. S. Modern oil extraction plant. Canad. Chem. Proc. Ind. **29:** 306–311. 1945.
28. Briggs, D. R., and Mann, Robert L. An electrophoretic analysis of soybean protein. Cereal Chem. **27:** 243–257. 1950.
29. Burnett, R. S., and Fontaine, T. D. Commercial peanut meal—peptization and extraction of nitrogenous constituents and color comparison of protein solutions. Ind. & Eng. Chem. **36:** 284–288. 1944.
30. ——— and Parker, E. D. Peanut meal plywood glue. Am. Soc. Mech. Engrs., Trans. **68:** 751–756. 1946.
31. ———. Peanut protein hydrates. Ind. & Eng. Chem. **37:** 861–864. 1945.
32. ———, Parker, E. D., and Roberts, E. J. Peanut protein hydrates. Utilization as tacky and remoistening adhesives. *Ibid.* **37:** 980–982. 1945.
33. Cartter, J. L., and Hopper, T. H. Influence of variety, environment, and fertility level on the chemical composition of soybean seed. U. S. Dept. Agr., Tech. Bull. 787. 1942.
34. Castillon, Leah E., and Altschul, A. M. Preparation of water-soluble products of gossypol and their toxicity to aquarium fish. Proc. Soc. Exp. Biol. & Med. **74:** 623–626. 1950.
35. ———, Karon, Melvin, Altschul, A. M., and Martin, F. N. Preparation of combination products of gossypol with glycine and dextrose and their toxicity toward mice. Arch. Biochem. & Biophys. **44:** 181–188. 1953.
36. ———, ———, ———, and ———. Castor beans in Texas. Texas Agr. Exp. Sta., Bull. 744. 1952.
37. Chang, Lie Tien. Sugar liquor defecation with soybean flour. Ind. & Eng. Chem. **43:** 654–659. 1951.
38. Cheng, F. W., and Arthur, Jett C., Jr. Viscosity of cottonseed protein dispersions. Jour. Am. Oil Chem. Soc. **26:** 147–150. 1949.
39. Clemen, Rudolf A. By-products in the packing industry. Univ. Chicago Press.
40. Coats, H. B., and Wingard, M. R. Effects of particle size on extraction rate. Jour. Am. Oil Chem. Soc. **27:** 93–96. 1950.
41. Cohn, E. J., Berggren, R., and Hendry, J. Studies in the physical chemistry of protein. III. The relation between the composition of zein and its acid and base properties. Jour. Gen. Physiol. **7:** 81–98. 1924.
42. ———, Hendry, J., and Prentiss, Adela M. Studies in the physical chemistry of protein. V. Molecular weight of proteins. Jour. Biol. Chem. **63:** 721–766. 1925.
43. Croston, C. Bradford. Stabilization of

zein filaments. Ind. & Eng. Chem. **42:** 482–484. 1950.

44. ——— and Evans, Cyril D. Stabilization of zein filaments by baking. Textile Res. **20**(12): 857–858. 1950.
45. ———, Evans, C. D., and Smith, A. K. Zein fibers—preparation by wet spinning. Ind. & Eng. Chem. **37:** 1194–1198. 1945.
46. Dilman, A. C., and Stoa, T. E. Flaxseed production in the North Central states. U. S. Dept. Agr., Farm. Bull. 1747. Rev. 1942.
47. Dillon, J. H. Tensile properties of newer fibers. Ind. & Eng. Chem. **44:** 2115–2122. 1952.
48. Dixon, T. *Ricinus communis*. Australasian Med. Gaz. **6:** 155–158. 1886–87.
49. Domingo, W. E. The development of domestic castor bean production. Econ. Bot. **7:** 65–75. 1953.

49*a*. Dunning, J. W. Solvent extraction of cottonseed oil. Oil Mill Gaz. **56:** 64–68. 1951.

50. Eagle, Edward, and Bialek, H. F. Toxicity and body weight-depressing effects in the rat of water-soluble combination products of gossypol, gossypol, and cottonseed pigment glands. Food Res. **17:** 543–549. 1952.
51. ———, Castillon, L. E., Hall, C. M., and Boatner, C. H. Acute oral toxicity of gossypol and cottonseed pigment glands for rats, mice, rabbits, and guinea pigs. Arch. Biochem. **18:** 271–277. 1948.
52. ———, Hall, Catherine M., Castillon, Leah E., and Miller, Charlotte Boatner. Effect of fractionation and treatment on the acute oral toxicity and on the gossypol and gossypurpurin content of cottonseed pigment glands. Jour. Am. Oil Chem. Soc. **27:** 300–303. 1950.
53. Eirich, F. R., and Rideal, E. K. The air driven ultracentrifuge. Nature **146:** 541–542, 551–552. 1940.
54. Evans, Cyril D., Croston, C. Bradford, and Van Etten, Cecil. Acetylation of zein fibers. Textile Res. **17**(10): 562–567. 1947.
55. ———, Foster, R. J., and Croston, C. Bradford. Preparation of zein by precipitation method. Ind. & Eng. Chem. **37:** 175–177. 1945.
56. ——— and Manley, Ralph H. Ternary solvents for zein. Ind. & Eng. Chem. **36:** 408–410. 1944.
57. ——— and ———. Solvents for zein. Primary solvents. *Ibid*. **33:** 1416–1417. 1941.
58. Flaxseed and linseed oil. A summary of information on uses, production, trade, and supply. U. S. Tariff Comm., Ind. Mater. Ser., Rep. M-7. Nov. 1952.
59. Fontaine, T. D., and Burnett, R. S. Peptization of nitrogenous constituents of solvent extracted peanut meal. Ind. & Eng. Chem. **36:** 164–167. 1944.
60. ———, Detweiler, S. B., and Irving, G. W. Improvement in the color of peanut and cottonseed proteins. *Ibid*. **37:** 1232–1236. 1945.
61. ———, Irving, George W., and Markley, K. S. Peptization of peanut and cottonseed proteins. *Ibid*. **38:** 658–662. 1946.
62. ———, Pons, Walter A., and Irving, George W. Protein-phytic acid relationship in peanuts and cottonseed. Jour. Biol. Chem. **164:** 487–507. 1946.
63. ———, Samuels, Carolyn, and Irving, G. W. Properties of peanut meal. Ind. & Eng. Chem. **36:** 625–627. 1944
65. Gorham, T. Analysis of Indian corn. Quart. Jour. Sci., Lit. & Arts **11:** 206–208. 1921.
66. Goring, D. A. I., and Johnson, P. An ultrafiltration method for the optical clarification of protein solutions in light scattering investigations. Jour. Chem. Soc. **1952:** 33–35. 1952.
67. Gorter, K. Zur Identität der Helianthsäure mit der Chlorogenicsäure. Arch. Pharm. **247:** 436–438. 1909.
68. Gortner, Ross Aiken, and MacDonald, Robert Theis. Studies on the fractionation of zein. Cereal Chem. **21:** 324–333. 1944.
69. Grau, C. R., and Almquist, H. J. Value of sunflower-seed protein. Proc. Soc. Exp. Biol. & Med. **60:** 373–374. 1945.
70. Gupa, S. S., Hilditch, T. P., and Riley, J. P. The fatty acids and glycerides of castor oil. Jour. Sci., Food & Agr. **2:** 245–251. 1951.
71. Guthrie, J. D., Hoffpauir, C. L., Stansbury, M. F., and Reeves, W. A. U. S. Dept. Agr., Bur. Agr. & Ind. Chem., AIC-61 (Rev.). 1949.
72. Halenke, A., and Kling, M. [Castor bean by-products]. M. Landw. Vers. Sta. **64:** 51. 1906.
73. Hansen, D. W., Brimhall, B., and Sprague, G. F. Relationship of zein to the total protein in corn. Cereal Chem. **23:** 329–335. 1946.
74. Heywang, Burt W., Bird, H. R., and Altschul, A. M. The effect of pure gossypol on egg hatchability and weight. Poul. Sci. **29:** 916–920. 1950.
75. Higgins, B. B., Holley, K. T., Pickitt,

T. A., and Wheeler, C. D. I. Peanut breeding and characteristics of some new strains. Ga. Agr. Exp. Sta., Bull. 213. 1941.

76. Hoffpauir, Carroll L. Peanut composition. Relation to processing and utilization. Agr. & Food Chem. **1:** 668–670. 1953.

77. Hogan, Joseph T., and Arthur, Jett C. Cottonseed and peanut meal glues. Resistance of plywood bonds to chemical reagents. Jour. Am. Oil Chem. Soc. **29:** 16–18. 1952.

78. ——— and ———. Cottonseed and peanut meal glues. Permanence of plywood glue joints as determined by interior and exterior accelerated cyclic service tests. *Ibid.* **28:** 272–274. 1951.

79. Hull, William Q., and Bangert, Walter G. Animal glue. Ind. & Eng. Chem. **44:** 2275–2284. 1953.

80. Irving, George W., Fontaine, Thomas D., and Warner, Robert C. Electrophoretic investigation of peanut proteins. I. Peanut meal extract, arachin and conarachin. Arch. Biochem. **7:** 475–489. 1945.

81. Johns, C. O., and Jones, D. B. The proteins of the peanut, *Arachis hypogaea.* I. The globulins arachin and conarachin. Jour. Biol. Chem. **28:** 77–87. 1916; **30:** 33–39. 1917. II. The distribution of the basic nitrogen in the globulins arachin and conarachin. Jour. Franklin Inst. **184:** 120–121. 1918. III. The hydrolysis of arachin. *Ibid.* **36:** 491–500. 1918.

82. Johnson, P., and Joubert, F. J. On the interaction of the globulin, arachin, with various ions. Jour. Polymer Soc. **7:** 605. 1904.

83. ———. The proteins of the ground-nut (*Arachis hypogaea*). Part I. The isolation and properties of the proteins. Trans. Faraday Soc. **42:** 28–45. 1946.

84. ——— and Shooter, E. M. The globulins of the ground nut. I. Investigation of arachis as a dissociation system. Biochem. et Biophys. Acta **5:** 361–375. 1950.

85. Jones, D. Breese. Proteins of the castor bean. Their preparation, properties, and utilization. Jour. Am. Oil Chem. Soc. **24:** 247–250. 1947.

86. Jones, D. B., and Csonka, F. A. Proteins of the cottonseed. Jour. Biol. Chem. **64:** 673–683. 1925.

87. Kabat, Elvin A., Heidelberger, Michael, and Bezer, Ada E. A study of the purification and properties of ricin. *Ibid.* **168:** 629–639. 1947.

88. Karon, M. L., Adams, Mabelle E., and Altschul, A. M. Electrophoretic analysis of peanut and cottonseed proteins. Jour. Phys. & Coll. Chem. **54:** 56–66. 1950.

89. ———, ———, and Newman, Seymore. The effect of temperature on the electrophoretic analysis of cottonseed meal extract. Jour. Colloid Sci. **7:** 407–413. 1952.

90. Kenyon, Richard L., Kruse, N. F., and Clark, S. P. Solvent extraction of oil from soybean. Ind. & Eng. Chem. **40:** 186–194. 1948.

91. Kodras, Rudolph, Whitehair, C. K., and MacVicar, Robert. Studies on the detoxication of castor seed pomace. Jour. Am. Oil Chem. Soc. **26:** 641–644. 1949.

92. Kunitz, M., and McDonald, Margaret R. Isolation of crystalline ricin. Jour. Gen. Physiol. **32:** 25–31. 1948.

93. Lieberherr, E. A few notes on Indian ground nuts. Volkart Bros., Bombay. 1928.

94. Lyman, Carl M., Chang, Wan Yuin, and Couch, J. R. Evaluation of protein quality in cottonseed meals by chick growth and by chemical index method. Jour. Nutrition **49:** 679–690. 1953.

95. Manley, Ralph H., and Evans, Cyril D. The critical peptization temperatures of zein in concentrated ethyl alcohol. Jour. Biol. Chem. **143**(3): 701–702. 1942.

96. ——— and ———. Binary solvents for zein. Ind. & Eng. Chem. **35:** 661–665. 1943.

97. Market potential for oilseed protein materials in industrial uses. Tech. Bull. No. 1043. Sept. 1951. [A report of Arthur D. Little, Inc., under contract as authorized by the Research and Marketing Act].

98. Meissl, E., and Böcker, F. Über die Bestandtheile der Bohnen von *Hispida.* Sitz-ber. Akad. Wiss. Wein, Math-nat. Klasse. Pt. I. **87:** 372–391. 1893.

99. Milligan, J. L., and Bird, H. R. The effect of processing variants on the nutritive value of cottonseed meal for chicks. Poul. Sci. **30:** 651–657. 1951.

100. Milner, R. T., Hubbard, J. E., and Wiele, Mary B. Sunflower and safflower seeds and oils. Oil & Soap **22:** 304–307. 1945.

101. Mitchell, H. H., and Hamilton, T. S. The importance of commercial processing for the protein value of food products. 1. Soybean, coconut and sun-

flower seed. Jour. Nutrition **29:** 13–25. 1945.

101*a*. Morrison, A. B., Clandinin, D. R., and Robblee, A. R. The effect of processing variables on the nutritive value of sunflower seed oil meal. Poul. Sci. **32:** 492–496. 1953.

102. Nagel, R. H., Becker, H. C., and Milner, R. T. Some physical factors affecting the dispersion of soybean protein in water. Cereal Chem. **40:** 463–471. 1938.

103. Ofelt, C. W., and Evans, Cyril D. Aqueous zein dispersions. Ind. & Eng. Chem. **41:** 830–833. 1949.

104. Olcott, H. S., and Fontaine, T. D. Composition of cottonseed. I. Solubility of nitrogenous constituents. Jour. Am. Chem. Soc. **61:** 2037–2040. 1939.

105. ——— and ———. Composition of cottonseed. III. Solubility of proteins in alkaline solutions of neutral salts. *Ibid.* **62:** 1334–1339. 1940.

106. ——— and ———. Effect of cooking on solubility of cottonseed-meal proteins. Ind. & Eng. Chem. **34:** 714–716. 1942.

107. Osborne, Thomas B. The vegetable proteins. 1924.

108. ———. Proteids of the flax-seed. Am. Chem. Jour. **14:** 629–661. 1892.

109. ——— and Campbell, George F. The proteids of the sunflower seed. Jour. Am. Chem. Soc. **19:** 487–494. 1897.

110. ——— and ———. The proteids of the soybean. *Ibid.* **20:** 419–428. 1898.

111. ———, Mendel, L. B., and Harris, I. F. A study of the proteins of the castor-bean with special reference to the isolation of ricin. Am. Jour. Physiol. **14:** 259–286. 1905.

112. ——— and Vorhees, C. G. The proteids of the cottonseed. Jour. Am. Chem. Soc. **16:** 778–785. 1894.

113. Persell, R. M., Pollard, E. F., and Gastrock, E. A. Solvent extraction of cottonseed. The Cotton Gin and Oil Mill Press **51:** 9–11, 24, 25, 30–32. 1950.

114. ———, Vix, H. L. E., Reuther, C. G., and Pollard, E. F. Pilot-plant fractionation of cottonseed. V. A preliminary cost study. Jour. Am. Oil Chem. Soc. **27:** 383–386. 1950.

115. Piper, Charles V., and Morse, William J. The soybean. 1943.

116. Pominski, Joseph, and Gordon, W. O. Note on the use of calcium hydroxide in the preparation of peanut protein. Jour. Am. Oil Chem. Soc. **30:** 88–89. 1953.

117. ———, Laborde, E. J., Cirino, V. O., and Vix, H. L. E. Processing variables in peanut protein preparations. *Ibid.* **28:** 508–512. 1951.

118. ———, Gordon, W. O., McCourtney, E. J., Vix, H. L. E., and Gastrock, E. A. Production of peanut protein. Ind. & Eng. Chem. **44:** 925–928. 1952.

119. Pons, Walter A., Jr., and Guthrie, John D. Determination of free gossypol in cottonseed materials. Jour. Am. Oil Chem. Soc. **26:** 671–676. 1949.

120. Porterfield, J. G., and Oppel, F. L., Jr. An experimental castor bean huller. Agr. Eng. **33:** 713–715. 1952.

121. Pulp and paper manufacture. Vol. II, pp. 40. Edited by Stephenson, J. 1951.

122. Ricker, R. L., and Morse, W. J. The correct botanical name for the soybean. Jour. Am. Soc. Agron. **40:** 190–191. 1948.

123. Ritthausen, H. II. Samen von *Helianthus annuus* (Sonnenblumen). Pfluger's Arch. **21:** 89. 1880.

124. Robinson, B. B. Fiber-flax production. U. S. Dept. Agr., Farm. Bull. 1728. Rev. 1940.

125. Rudkin, George O., and Nelson, J. M. Chlorogenic acid and respiration of sweetpotatoes. Jour. Am. Chem. Soc. **69:** 1470–1475. 1947.

126. Satow, Sadakichi. Researches on oil and proteids. Extraction from soybean. Tohoku Imp. Univ., Tech. Rep. **2**(2): 41–124. 1921.

127. Scallet, Barrett L. Zein solutions as association-dissociation systems. Jour. Am. Chem. Soc. **69:** 1602–1608. 1947.

128. Schoenleber, L. G., and Hurst, W. M. Performance of castor bean hulling plants. Agr. Eng. **33:** 708–710, 712. 1952.

129. Shewfelt, A. L., and Worthington, Oliver J. The extraction of pectin from sunflower heads. Food Tech. **7:** 336–340. 1953.

130. Sorenson, J. W. Mechanization of peanut production in Texas. Agr. Eng. **33:** 561–562. 1952.

131. Spadaro, J. J., Persell, R. M., Murphey, C. H., Jr., Vix, H. L. E., McCourtney, E. J., Hecker, J. L., Pollard, E. F., and Gastrock, E. A. Pilot-plant fractionation of cottonseed. I. Disintegration of cottonseed meats. Jour. Am. Oil Chem. Soc. **25:** 345–353. 1948.

132. ———, ———, Reuther, C. G., Jr., Vix, H. L. E., Laborde, E. J., Latham, J. W., Jaeger, R. L., Pollard, E. F., and Gastrock, E. A. Pilot-plant fractionation of cottonseed. III. Process development of differential settling. *Ibid.* **27:** 336–343. 1950.

133. Spies, Joseph R., and Coulson, E. J. The chemistry of allergens. VIII. Isolation and properties of an active protein-polysaccharidic fraction CB-1A from castor bean. Jour. Am. Chem. Soc. **65:** 1720–1725. 1943.

134. ———, ———, Chambers, Dorris C., Bernton, Harry S., and Stevens, Henry. The chemistry of allergens. IX. Isolation and properties of an active carbohydrate-free protein from castor beans. *Ibid.* **66:** 748–753. 1944.

135. Smith, Allan K., Belter, Paul A., and Johnsen, Vernon L. Peptization of soybean meal protein. Effect of method of dispersion and age of beans. *Ibid.* **29:** 309–312. 1952.

136. ——— and Circle, Sidney J. Peptization of soybean protein. Extraction of nitrogenous constituents from oil-free meal by acids and bases with and without added salts. Ind. & Eng. Chem. **30:** 1414–1418. 1948.

137. ———, ———, and Brother, George H. Peptization of soybean proteins. The effect of neutral salts on the quantity of nitrogenous constituents extracted from oil-free meal. Jour. Am. Chem. Soc. **60:** 1316–1320. 1938.

138. ——— and Johnsen, Vernon L. Sunflower seed protein. Cereal Chem. **25:** 399–406. 1948.

139. ———, ———, and Beckel, A. C. Linseed protein. Alkaline dispersion and acid precipitation. Ind. & Eng. Chem. **38:** 353–356. 1946.

140. ———, ———, and Derges, Robert E. Denaturation of soybean protein with alcohols and with acetone. Cereal Chem. **28:** 325–333. 1951.

141. ——— and Max, Herbert J. Soybean protein. Adhesive strength and color. Ind. & Eng. Chem. **34:** 817–820. 1942.

142. ———, ———, and Chandler, Philip. The dispersion of protein in aqueous formaldehyde solutions. Jour. Phys. Chem. **43:** 347–357. 1939.

143. Stansbury, Mack F., Field, Elsie T., and Guthrie, John D. The tannin and related pigments in the red skins (testa) of peanut kernels. Jour. Am. Oil Chem. Soc. **27:** 317–321. 1950.

144. ——— and Hoffpauir, Caroll L. The estimation of skin content of peanut meals and relative skin pigment content of isolated protein. *Ibid.* **29:** 370–372. 1952.

145. Stillmark, H. Ueber ricin; ein giftiges Ferment. Aus den Samen von *Ricinus comm.* L. und einigen anderen Euphoribiaceéen. Schnakenburgs Buchdruckeréi, 123 pp. Dorpat (Inaug. Dis.). 1888.

146. Sure, Barnett, Easterling, Leslie, Dowell, Jay, and Crudeys, Mary. Cottonseed meals. Influence of processing on protein values. Agr. & Food Chem. **1:** 82–84. 1953.

147. Swallen, L. C. Zein—a new industrial protein. Ind. & Eng. Chem. **33:** 394–398. 1941.

148. Traill, David. Some trials by ingenious inquisitive persons: Regenerated protein fibers. Jour. Soc. Dyers & Colour. **67:** 257–270. 1951.

149. U. S. Dept. Agr., Agricultural Statistics. 1951.

150. Van Horn, Donald L. Castor bean production. U. S. Dept. Agr., Farm. Bull. 2041. 1952.

151. ———. Production and uses of castor beans. Agr. Eng. **33:** 711–712. 1952.

152. Vassel, Bruno, and Nesbit, L. I. The nitrogenous constituents of flaxseed. II. Isolation of a purified fraction. Jour. Biol. Chem. **159:** 571–584. 1945.

153. Vickery, H. B. The proteins of plants. Physiol. Rev. **25:** 347–376. 1945.

154. Vilogen, N. J. An investigation into the composition of the soybean in South Africa. Union S. Afr., Dept. Agr. & For., School of Agr., Potchefstroom, Sci. Bull. 169.

155. Vines, S. A. On the proteid substances contained in the seeds of plants. Jour. Physiol. **3:** 93–114. 1880.

156. Vix, H. L. E., Spadaro, J. J., Murphey, C. H., Jr., Persell, R. M., Pollard, E. F., and Gastrock, E. A. Pilot-plant fraction of cottonseed. II. Differential settling. Jour. Am. Oil Chem. Soc. **26:** 526–530. 1949.

157. ———, ———, Westbrook, R. D., Crovetto, A. J., Pollard, E. F., and Gastrock, E. A. Pre-pilot-plant mixed solvent flotation process for separating pigment glands from cottonseed meats. *Ibid.* **24:** 228–236. 1947.

158. Watson, C. C., Arrhenius, Sven, and Williams, J. W. Physical chemistry of zein. Nature **137:** 322–323. 1936.

159. Weible, R. O. The castor oil plant in the United States. Econ. Bot. **2:** 273–283. 1948.

160. White, W. J., and Putt, E. D. Sunflower production for grain. Dom. Forage Crop Lab., Saskatoon, Sask. Spec. Pam., War. Prod. Ser. 1943.

161. Wrenshall, C. Lewis. The American peanut industry. Econ. Bot. **3:** 158–169.

The Essential Oil Industry of Australia

This industry is founded primarily on eucalyptus oils from several species. The more important minor endemic oils are those of Australian sandalwood and of two or three genera known as "tea-trees". Various factors have prevented exploitation of other potentially valuable native oils. Among exotic oils, only that of lavender has been commercially produced.

A. R. PENFOLD AND J. L. WILLIS
Museum of Applied Arts and Sciences, Sydney, Australia

Introduction

Australia is extraordinarily rich in essential oil-yielding plants. This island continent of about three million square miles, approximately the size of the U.S.A., is renowned for the number of oil-yielding genera, such as *Baeckea, Backhousia, Boronia, Eucalyptus, Kunzea, Leptospermum, Melaleuca* and *Zieria,* belonging to the great families Myrtaceae and Rutaceae. These dominant oil-bearing families constitute about 90% of the flora, which is not surprising when the ubiquitous eucalypts alone occupy in numbers about three-quarters of the total flora of Australia. The high degree of endemism seems to be correlated with the unique nature of the essential oil-bearing flora.

It is significant that one of the first articles of export from the newly established Colony of New South Wales in 1788 was a quarter gallon of the essential oil drawn from the leaves of a eucalypt growing on the shores of Port Jackson where Sydney now stands. This oil, obtained by Surgeon-General White of the First Fleet, was sent to England for test and was found to be more efficacious in the removal of "cholicky complaints" than the oil obtained from the English peppermint herb. The name "Sydney Peppermint" was accordingly given to this eucalypt which is now know as *Eucalyptus piperita* Sm.

Eucalyptus oil, next to timber, is Australia's most important forest product. The essential oil industry in Australia really began in 1852 when Joseph Bosisto, C.M.G., a Victorian pharmacist, commenced operations with a crudely constructed still at Dandenong Creek, Victoria. He used the leaves of *Eucalyptus amygdalina* Labill. (now *E.*

australiana Baker and Smith) which grew profusely in that district. From that date to the present time, eucalyptus oil has attracted considerable attention, not only in Australia but in all parts of the world. Apart from that of *Eucalyptus* species, very few essential oils have been distilled commercially in Australia. Those few are the oils of Australian sandalwood (*Eucarya spicata* Sprag. and Summ.), experimentally distilled in 1875 by Schimmel and Company of Leipzig, Germany; of *Leptospermum citratum* distilled since about 1930; of Huon pine wood (*Dacrydium franklinii*), produced commercially in the early days of this century; and of *Melaleuca alternifolia* Cheel (tea-tree oil), which has been marketed since 1928.

FIG. 1. Main distillation areas in Australia.

Botany

Eucalyptus oils are the most important commercial essential oils produced in Australia. The genus *Eucalyptus* was named by L'Heritier in 1788, the word being derived from the Greek *eu* (well) and *kalypto* (I cover) in allusion to the operculum, or lid, which covers the stamens until they are fully developed. (Operculum = calyx, at least in some species). The genus is typically Australian, although some species have been recorded from New Guinea, Timor and the Philippine Islands. The extensive plantations in Algiers and other parts of Africa, California, India, New Zealand, Spain, Brazil, Belgian Congo and other parts of the world were planted with seed obtained originally from Australia.

Eucalypts are widely distributed over the whole of the Australian continent. They range from the dwarfed and stunted forms called " mallees ", which occur in the areas of low rainfall, to the tall and luxuriant trees which grow on the coastal and mountainous regions. Some species are at home at sea level, whilst others thrive on the snow-line of the Australian Alps. No genus has been more thoroughly investigated by systematic botanists, commencing with the discovery of the first species (*E. obliqua* L'Heritier) in 1777 by David Nelson on Captain Cook's third voyage, to the work of F. von Mueller, George Bentham, J. H. Maiden, R. T. Baker and W. F. Blakely.

Unfortunately competition amongst rival botanists, although it stimulated intensive investigation, resulted in a multiplicity of species. Consequently there is a confusing and voluminous literature which has tended to discourage instead of attracting the interest of a wider circle of systematic botanists in the study of the eucalypts.

Physiological Forms

Probably one of the most important results of the investigation into the oil-yielding flora of Australia has been the discovery of forms or varieties of well-known species, indistinguishable from one another on morphological evidence but yielding oils of diverse chemical composition. These are termed " physiological forms ". Some idea of the influence which these have had on the Australian essential oil industry, more particularly on the eucalyptus oil industry, can be gauged from the following example:

An area of 3,000 acres of supposed *Eucalyptus dives* had been rejected for exploitation because the oil from that species would not be worth more than 1/- per lb. It was subsequently found that leaves taken from this area of country yielded on distillation an oil worth 2/6 per lb. This fact brought the area in question into immediate commercial production. This species, which was subsequently called *E. dives* var. " C ", could not be distinguished from the " type " by any known botanical means. The differences in composition of the respective essential oils (one had an odour resembling " peppermint ", the other typical " eucalyptus ") were the only distinguishing features. For convenience it is the practice in Australia to call the first known form of a species the " type "; each succeeding form is called Variety " A ", " B ", " C ", etc.

There is considerable misunderstanding about the origin of the physiological forms. A number of scientists still cling to the view that the marked differences in chemical composition are due to soil or climatic conditions, but the accompanying illustration (Fig. 2) should dispel any such erroneous impressions. The tree on the left is *Eucalyptus australiana* " type ", the oil of which contains 70% of cineole with α-terpineol and citral. The tree on the right yields an oil containing less than 10% cineole; it consists mainly of l-α-phellandrene and other terpenes with the alcohol l-terpinen-ol-4 (Var. " A ").

Physiological forms are not confined to the eucalypts but have been found in many genera of the families Myrtaceae and Rutaceae, e.g., *Leptospermum*, *Melaleuca*, *Boronia* and *Backhousia*.

Production

The principal producing areas are located on the east coast of Australia, extending westward in the southeast portion of the continent, where the high-yielding species of commercial importance abound.

Practically the whole of the eucalyptus oil produced in Australia is derived from natural stands. Although there are approximately 700 species and varieties of

FIG. 2 (*Upper*). Two trees of *Eucalyptus australiana* at Rosewood, N.S.W. The tree on the left, the "type", contains an entirely different oil to the physiological form called variety "A" on the right.

FIG. 3 (*Lower*). Typical field still operating in southern N.S.W. The ship's tanks on the left are closed by lids fastened with beams of wood and wedges. The 400-gallon tank embedded on the right is a hot-water reservoir for maintaining a constant level of water in these directly fired stills. The derrick is used for unloading.

TABLE I

APPROXIMATE TOTAL AUSTRALIAN PRODUCTION OF EUCALYPTUS OILS

Year	N.S.W.	Victoria	South Australia	Queensland	Total
1947–48	1,020,000 lbs.	900,000 lbs.	35,000 lbs.	10,000 lbs.	1,965,000 lbs.
1948–49	600,000 lbs.	600,000 lbs.	35,000 lbs.	5,000 lbs.	1,240,000 lbs.
1949–50	430,000 lbs.	670,000 lbs.	35,000 lbs.	....	1,135,000 lbs.
1950–51	850,000 lbs.	800,000 lbs.	60,000 lbs.	....	1,710,000 lbs.
1951–52	875,000 lbs.	830,000 lbs.	....	....	1,705,000 lbs.
1952–53	300,000 lbs.	880,000 lbs.	....	....	1,180,000 lbs.

eucalypts, of which about 200 have been examined for essential oils, fewer than 20 are exploited today for the volatile oils. Production is usually centered upon one large town in perhaps several hundred square miles of oil-producing bush. Many independent distillers produce oil from their own stands and then send it to a bulk buyer in the nearest town. From here it is transported, either by road or rail, to the refineries in Sydney and Melbourne. There are also many distillers operating under contract on behalf of large exporters. Nearly three and a half million pounds of eucalyptus oil, worth £1,230,000 (Australian), were produced in the two years 1951–52, of which 70% was exported.

The approximate production figures for the various oil-producing States of Australia for the years 1947–48 to 1952–53, inclusive, are given in Table I. Exact production figures are not available, as there is no official check on distillers operating on other than lands owned by the Crown. The export figures for eucalyptus oil for the same years are given in Table II, together with the figures for Australian sandalwood oil, patchouli oil and miscellaneous other oils. The latter two items are mainly made up of oils imported into the country for re-export, and for the most part do not refer to Australian produced oils.

Distillation Practice

Eucalyptus Oils (*Eucalyptus* spp.). When an area of country, which may vary from about 100 to 5,000 acres or more according to the species to be worked, has finally been selected, and certain formalities such as obtaining a licence from the various Forestry Departments and permission to use a still from the Department of Trade and Customs have been complied with, the dis-

TABLE II

EXPORTS OF ESSENTIAL OILS FROM AUSTRALIA DURING THE YEARS 1947–48 TO 1952–53

Year	Eucalyptus oils		Patchouli oil		Sandalwood oil		Other essential oils	
	Weight	Value	Weight	Value	Weight	Value	Weight	Value
1947–48	1,481,418 lbs.	£A323,894	1,546 lbs.	£A6,473	18,283 lbs.	£A38,327	199,116 lbs.	£A42,201
1948–49	765,195 lbs.	£A138,304	2,113 lbs.	£A8,664	7,373 lbs.	£A16,118	42,472 lbs.	£A32,829
1949–50	680,802 lbs.	£A147,355	1,280 lbs.	£A4,414	10,701 lbs.	£A22,889	74,469 lbs.	£A56,331
1950–51	1,219,762 lbs	£A468,680	Nil	....	3,743 lbs.	£A 9,629	37,207 lbs.	£A30,857
1951–52	1,254,618 lbs.	£A445,206	Nil	....	6,214 lbs.	£A19,397	74,750 lbs.	£A35,330
1952–53	721,330 lbs.	£A215,283	Nil	....	Nil	.....	37,965 lbs.	£A44,148

NOTE: No patchouli oil is produced in Australia. The figures for patchouli oil given above refer to oil which has been imported into the country for re-export. The same applies to the figures for "other essential oils", although in this case Australian produced oils are represented to the extent of a few percent.

FIG. 4 (*Upper*). Field still operating in eastern Australia with separate outlets running into a common condenser. These stills are set in the bank of a creek and are fired with wood. The drum on the right acts as a chimney for the smoke.

FIG. 5 (*Lower*). Field still operating in southern N.S.W. The tank on the left is a reservoir for holding water pumped from the creek. This photograph shows the outlet running from the stills to the condenser lying in the dam on the left.

tiller may proceed to collect leaves and to distil the oil. Trees of the selected species are cut down to within one or two feet of the ground (in some instances the distillers prefer to cut down to ground level, according to species and local conditions), and the leaves and terminal branchlets are removed either with a hand axe or a cane cutter's knife, an operation usually requiring the services of two men. Regrowth from the stumps is ready for cutting after two to three years. The leaves are then transported to the still which is usually established on the bank of a stream or creek. Four-hundred-gallon ship's tanks, measuring four feet by four feet by four feet, directly fired with wood or spent leaves from a previous distillation, are the most convenient for distillers working in rough and mountainous country, as they are readily dismantled and easily transported from site to site. They are usually coupled together and operated in pairs. These tanks hold from 800 to 1000 pounds of leaves and terminal branchlets. During the past few years larger tanks measuring seven feet by five feet by five feet, used as pontoons by army engineers during World War II, have been introduced.

The method of working is to place 80–100 gallons of water in each tank and to pack the leaves tightly upon a grid supported upon the bottom. Before the lid is put in position, a thick mixture of mud or clay is placed along the flange. On top of this is placed a strip of hessian or similar packing material, and a second layer of clay is applied. The lid is then lowered on to the flange and fastened by means of cross timbers, wooden wedges and iron stirrups. The stirrups are attached to the tank. The still is built upon a support of bricks or stones and a wood fire is placed beneath. When the water boils, the steam passing up through the leaves separates the oil from the plant cells and carries it over in a vaporous state into a long iron pipe which acts as a condenser. This piping is attached to the still near the top and is conducted under the water of a stream or creek. The oil and water condense in the pipe and flow out into a suitable receptacle where the oil floats upon the surface of the water and is ultimately separated. The period of distillation varies from three to 18 hours, according to the species. This particular type of crude field still represents about 90% of the working stills on the east coast of Australia.

Where large areas of country are exploited, particularly in the "mallee" country (non-mountainous flat land), large stills operated by pressure boilers have been installed. This modern method of distillation is gradually being extended to all areas, particularly where the eucalypts are preserved for oil production.

These large distilleries are usually located in close proximity to the areas being cut over and to transport facilities. In addition, the distilleries are frequently near the distiller's residence. Living quarters for the cutters are sometimes provided close to the distillery. The cooling water for these modern units is usually supplied from a dam scooped out of the earth. Most of these plants are large installations of a permanent character with deep underground stills (or vats, as they are called locally) supplied with steam from a large horizontal boiler set in brickwork. The plants are housed in large corrugated iron sheds. The vats are usually cylindrical in shape and are set in the ground with six inches to 12 inches protruding above ground level. They range from five to eight feet in diameter and from nine feet to 14 feet in depth. They hold from two to five tons of fresh leaves and terminal branchlets.

The crude oils obtained from the stills are first tested by the bulk buyers at the point of production, and after refining at

FIG. 6 (*Upper*). Community distillation unit at Taradale Crossing, southern N.S.W. The plant consists of two $5' \times 5' \times 5'$ tanks separately attached to a common condenser. This unit is supplied with steam from a horizontal boiler and is unique, for it can be operated by anyone provided they sell the oil to the owners.

FIG. 7 (*Lower*). Part of large distillery at Rosewood, N.S.W. The large still in the foreground is typical of the stills used in the "mallee" country of Victoria. They consist of circular brick pits 11′6″ deep by 6′6″ wide, and extending about 1 foot above ground level. The steam for these units is supplied from a Cornish boiler operating at 40 lbs. per square inch but with a great volume of steam. A short length of railway line with truck carries spent leaves to dump for burning.

the distilleries they are tested according to the requirements of the various Pharmacopoeias (British and U.S.A.) or other specific Australian requirements. The refined oils are packed in 44-gallon drums for export to Europe and the U.S.A.

A number of Australian essential oils are sold according to the species, but many eucalyptus oils are sold on a composition basis, viz., a minimum cineole content of 65% or a minimum piperitone content of 40%. Efforts to sell all eucalyptus oils on a species basis have proved unsuccessful. European buyers invariably seek supplies of the oil of *Eucalyptus globulus* Labill. This species is not exploited in Australia today on account of its low yield, 0.75% compared with 2–4% from other species which have replaced it. (*E. globulus* oil is obtained only from plantations established in other countries.) Adulteration of Australian essential oils is comparatively rare on account of its ready detection.

Tea-Tree Oil (*Melaleuca alternifolia* Cheel.) Collection of leaf material differs from that in operation for eucalyptus leaves. The trees are cut down to within five or six feet of the ground and the limbs removed. The leaves are removed with a cutting knife and allowed to drop upon squares of hessian which hold from 40–80 lbs. The foliage is then carted to the distillery.

After cutting the original trees, new growth known as "ratoon" makes its appearance. This new growth is ready for cutting within 18 months to two years, according to seasonal conditions. The process of distillation is very similar to that employed for the production of eucalyptus oil.

Australian Sandalwood Oil (*Eucarya spicata* Sprag. and Summ.). There is little authentic information available about the commercial process of production. It is understood, however, that it is one of solvent extraction and steam distillation of the concentrated extract. The billets of wood are collected over a very wide area of the desert regions of Western Australia. They are then forwarded to the factories in Perth for processing.

Huon Pine Wood Oil (*Dacrydium franklinii*). The only other wood oil produced in Australia was derived from the waste wood and sawdust from the milling of logs of the well-known Huon pine of Tasmania. The oil was obtained by a direct process of steam distillation. Unfortunately the oil has disappeared from the market through inaccessibility of the remaining stands.

Boronia Flower Oil (*Boronia megastigma* Nees.). The most appropriate method of recovering the natural floral oil from the West Australian brown boronia is by extraction with petroleum ether. This method yields a concrete from which the alcohol-soluble absolute can be obtained by the usual methods. The flower collectors transfer the day's harvest to drums of 60 gallons capacity containing a sufficient quantity of petroleum ether with which the perfume is removed. The solvent acts as a preservative whilst the blossoms are in transit. The drums containing the blossoms and solvent are transferred to the factory where extraction is completed and the solution concentrated in vacuo. The resulting concrete contains all the volatile oil and the natural flower waxes. The flowers were originally steam distilled, but only a small part of the oil contained in the flowers was obtained; moreover, the oil possessed an odour quite different from that of the flower itself.

Processing

Eucalyptus Oils (*Eucalyptus* spp.). Crude eucalyptus oil, when received from the country centre, is subjected to re-distillation in one of the main refineries. Small quantities of water and objectionable volatile aldehydes (prin-

FIG. 8. *Eucalyptus citriodora* at an Experimental Plantation of the Museum of Applied Arts and Sciences, Sydney. These trees are 2½ years of age from seed. When cut 6 months later, they averaged 16 feet in height.

cipally isovaleric) are removed in this way, and the middle fraction, usually 85–90% of the total oil and containing not less than 70% cineole, is marketed. The residue, consisting of α-terpineol, sesquiterpenes, phenols and aromatic aldehydes, is used as a source of raw material for some of these isolates or in the manufacture of disinfectants.

Several eucalyptus oils which were regular articles of commerce have been replaced by others giving higher yields of oil of superior quality. Besides, stands of the newer species are more readily accessible. In this exchange *E. cinerea* F.v.M., *E. cneorifolia* D.C., *E. globulus*, *E. smithii* R. T. Baker and *E. vernicosa* Hook. f. have been supplanted by *E. australiana*, *E. dives* var. "C", *E. polybractea* and other species.

The crude oil of *E. dives* "type" upon receipt at the distilleries in the large capital cities is assayed for piperitone content, and if not below 45% it is subjected to distillation under reduced pressure. A technical grade of piperitone assaying 90–95% of actual ketone is thus produced. It is exported for the manufacture of synthetic thymol and menthol, although considerable quantities are used in Australia for a similar purpose. Thymol and menthol of Australian manufacture are also exported.

The terpene *l*-α-phellandrene, which is the principal constituent of the first fraction (40%) in the distillation of *E. dives* oil, is utilized to a limited extent in Australia as a solvent and in admixture with other eucalyptus oils for mineral flotation purposes.

The crude oil of *E. macarthuri*, which is produced in relatively small quantities, is subjected to re-distillation, whereby the objectionable aldehydes and low boiling esters are separated from the main fraction which consists principally of geranyl acetate with geraniol. The still residue, which varies from 15–20% of the total oil constituents, consists largely of eudesmol, a well-known sesquiterpene alcohol. Although eudesmol has little commercial value today, it was used extensively during World War II as a very satisfactory fixative for certain perfumes.

Tea-Tree Oil (*Melaleuca alternifolia* Cheel). This oil needs little treatment beyond drying and filtering before it is marketed for dental and surgical practice under various proprietary names, of which the best known are "Ti-trol" (the oil) and "Melasol" (40% oil in emulsion form). The cineole content should not exceed 10%, as this renders the oil unsuitable for dental and medical work. The main therapeutic constituents are terpenes (mainly α and γ terpinene), cymene and *l*-terpinen-4-ol in a complex mixture.

Endemic Medicinal Oils

	Yield of oil per 1,000 lbs. of foliage	Principal constituents
Eucalyptus polybractea	20 lbs.	Cineole 80–88%
E. australiana	30 "	" 70–75%
E. dives var. "C"	30–33 "	" "
E. elaeophora / *E. sideroxylon* / *E. leucoxylon*	20–25 "	" "
E. viridis	15–20 "	" 70–80%
E. dumosa	15–20 "	" 70%
E. oleosa	10–20 "	" 54–80%
Melaleuca alternifolia	18 "	α & γ terpinene, cymene *l*-terpinen-4-ol

Eucalyptus Oils. The oils from all the eucalypt species are rich in cineole and readily meet the requirements of the various pharmacopoeias which demand a minimum content of 70%.

E. polybractea R. T. Baker. This small tree is a typical "mallee"—a dwarfed eucalypt having several stems growing from the main root stock. It occurs in extensive stands in the low rainfall areas of New South Wales and Victoria. The principal producing areas

are around Wyalong in New South Wales and Bendigo in Victoria.

Production of oil from this species is not so great as formerly, since considerable areas of "mallee" country have been converted into wheat lands. On the other hand, several large distillers and exporters have taken steps to preserve this species on their properties. It is expected that by this means young and more vigorous growth of *E. polybractea* for oil production will result. There is an urgent need for the preservation of this species, principally on account of the large amount of cineole in the oil. *E. polybractea* provides about 33% of the total eucalyptus oil production of Australia. Commercial cineole of 99% purity, often called Eucalyptol, is prepared from the oil of this species. The bulk of the Australian production is exported.

E. australiana Baker and Smith. This is a medium-sized forest tree with fibrous bark, characteristic of that group of eucalypts called "Peppermints". It occurs in extensive belts on the main Dividing Range of New South Wales and Victoria. This species, together with *E. dives* var. "C", provides about 20% of the total eucalyptus oil production of Australia.

There is a steadily increasing demand for the oil of this species because, with the exception of *E. dives* var. "C", it is probably the finest eucalyptus oil for medicinal purposes produced in Australia today. The high content of cineole (70%) in association with α-terpineol and some citral (3–5%) impart to the oil a most refreshing aroma.

E. dives Schauer. var. "C". This is one of the most robust eucalypts belonging to the "Broad-leaved Peppermint" group. It is a physiological form of the well-known *Eucalyptus dives* "type" with which it is, therefore, botanically identical. The oil in both chemical and physical characters is practically identical with that obtained from *E. australiana;* it bears no resemblance whatsoever in chemical composition to the oil of *E. dives* "type". *E. dives* var. "C" grows in good stands in southern New South Wales.

E. elaeophora F.v.M. is a rather low stunted tree with fibrous bark known vernacularly as "Apple Jack". This tree grows in Victoria and in the central districts of New South Wale.

E. sideroxylon Woolls. This species, commonly known as the "Red Flowering Ironbark", is a medium-sized forest tree with a deeply furrowed black bark. It occurs in the coastal area of eastern Australia.

E. leucoxylon F.v.M. This moderate-sized tree with smooth bark is known as "White Gum". It occurs in Victoria and South Australia.

Commercial production of eucalyptus oil from the three preceding species is restricted to Victoria. The leaves of all three species are invariably distilled together, the "Ironbark" and "Apple Jack" predominating. The mixed commercial oil is known as "Apple Jack" and "Iron Bark". This type of oil, which constitutes the bulk of the eucalyptus oil distilled and exported from Victoria, represents about 20% of Australia's total eucalyptus oil production.

E. viridis R. T. Baker. This shrub, known as the "Green", "Red" or "Brown" Mallee, occurs in the "mallee" country of New South Wales and Victoria. Commercial production of the oil is restricted to the State of Victoria where good areas of the species are found in association with *E. sideroxylon.*

E. dumosa Schauer. This, too, is a "mallee" which occurs in the oil-producing areas of New South Wales and Victoria, where *E. polybractea* also abounds. The foliage is distilled either alone or in admixture with *E. polybractea,* especially where stands have been found to yield oil in greater quantity and of higher cineole content than those formerly examined.

E. oleosa F.v.M. This small tree—a typical "mallee"—occurs in extensive patches throughout the "mallee" country of New South Wales, Victoria, South Australia and West Australia. The foliage is rarely distilled alone but usually in admixture with other "mallees" such as *E. dumosa* or *E. polybractea*. There are records of *E. oleosa* having been distilled alone by a leading eucalyptus oil distiller in South Australia. The leaves and terminal branchlets yielded from 0.9–2% of oil (average 1.4%) containing from 54–80% cineole (average 64%).

Tea-Tree Oil. This oil is noted for its bactericidal properties. The botanical source, *Melaleuca alternifolia* Cheel, is a small tree with narrow leaves and paper bark, which follows the water courses and flourishes in swampy situations. It occurs in large stands in the coastal districts of eastern Australia, extending from Stroud in northern New South Wales through the coastal rivers to southern Queensland.

Many stands of this tree suffer severely from time to time through drought (the tree thrives best with its feet in water) and bush fires. The essential oil, which is of a pale yellow colour and possesses a pleasant nutmeg odour, is marketed under various proprietary names. Its high germicidal activity, pleasant odour and non-poisonous and non-corrosive properties have resulted in extensive application of it in surgical and dental practice. The efficacy of the oil is not due to any one constituent but to the complex natural blend of terpenes (mainly α & γ-terpinene), cymene, *l*-terpinen-4-ol and other substances. (The cineole content should be below 10%, otherwise its efficacy is reduced.) Present production is 50,000–60,000 lbs. per annum. Large quantities of the oil were used in munition factories during World War II, when it was found that 1% of the oil incorporated in machine "cutting oils" greatly reduced skin injuries caused by metal filings and turnings.

Endemic Industrial Oils

	Yield of oil per 1,000 lbs. of foliage	Principal constituents
Eucalyptus australiana var. "B" (*E. phellandra*)	30–50 lbs.	Phellandrene (35–40%), cineole (20–50%), terpineol
E. dives "type"	30–45 lbs.	Piperitone (45–53%), phellandrene
E. numerosa var. "A"	45 lbs.	Piperitone (50%), phellandrene (40%)

Eucalyptus Oils. *E. australiana* Baker and Smith var. "B". This species, one of the "Narrow-leaved Peppermints" and sometimes known as *E. phellandra* Baker and Smith, is botanically identical with *E. australiana* and is thus a physiological form. It occurs extensively on the great Dividing Range of New South Wales and Victoria. No other species has been exploited so extensively for industrial purposes, since the oil is ideally suited for the manufacture of disinfectants and deodorants. Thousands of tons of the oil of this species have been marketed during the past 50 years.

E. dives Schauer. "type", commonly known as the "Broad-leaved Peppermint", is common throughout the whole of the coastal ranges of New South Wales and Victoria. It is a moderate sized tree, with greyish-brown stringy bark, which bears a very close resemblance to other species of eucalypts called the "Narrow-leaved Peppermints". The oil contains from 45–53% of the ketone piperitone and has been for many years a noted source of raw material for the manufacture of synthetic thymol and menthol. Only small quantities of the oil find application today for the separation of metallic sul-

phides in the flotation process of mineral separation.

E. numerosa Maiden var. "A". This tree is a physiological form of *E. numerosa*. It often occurs in association with the "type", but relatively pure stands of var. "A" have been located and exploited since it was first observed in 1932. The tree is known as "White Top", or "River White Gum", and occurs plentifully on the river banks and mountain ranges of eastern New South Wales. It is a fairly tall tree with narrow leaves and closely resembles the "Narrow-leaved Peppermint", *Eucalyptus australiana*. A distinctive feature is the clean white upper limbs free from bark. The oil closely resembles that of *E. dives* "type"; it contains 40% of *l*-α-phellandrene and other terpenes, and about 50% of *l*-piperitone.

Endemic Perfumery Oils

	Yield of oil per 1,000 lbs. of foliage	Principal constituents
Eucalyptus macarthuri	2 lbs.	Geranyl acetate (60–65%), geraniol and eudesmol
E. citriodora	8–10 lbs.	Citronellal (65–85%)
Leptospermum citratum	10–15 lbs.	Citral and citronellal (75–85%)
Backhousia citriodora	10–15 lbs.	Citral (90–95%)
Boronia megastigma (Concrete otto of Brown Boronia)	40–80 lbs. (ex flowers)	Ionones
Eucarya spicata (Australian sandalwood)	10–30 lbs.	90–95% alcohols $C_{15}H_{24}O$

Eucalyptus Oils. *E. macarthuri* Deane and Maiden. This very attractive and foliaceous tree, known as the "Paddy's River Box" or "Camden Woollybutt", grows in swampy or low-lying land and on the banks of streams and rivers in southern New South Wales. The yield of oil from the leaves and terminal branchlets of forest trees varies from 0.15 to 0.2%, although at certain periods of the year yields up to 0.5% have been obtained. The yields of oil from cultivated trees have varied from 0.5 to 1%. The odour of the leaves when crushed between the hands readily distinguishes the species from practically all other eucalypts. The bark contains an oil of composition similar to that of the leaf but in lower yield, usually about 0.15%. The oil differs from most other eucalyptus oils of commerce in the absence of cineole or phellandrene; it consists principally of geranyl acetate (60–65%), some free geraniol and about 15% of eudesmol. The crude oil is used in perfumery as a source of geranyl acetate, but mainly in Australia as a denaturant of alcohol.

E. citriodora Hook. is a large tree often attaining great height, with a smooth whitish to pale pink bark, sometimes with greyish spots. It is essentially a Queensland tree, being particularly abundant in the north coast area of that State. It is commonly known as the "Citron-scented Gum" or "Spotted Gum". It is readily identified by its characteristic fruit and by the deliciously fragrant "citronella" odour of the crushed leaves. *E. citriodora* has been extensively cultivated as an ornamental tree throughout Australia. It is grown commercially in the Seychelle Islands, Java, South Africa, Guatemala, the Belgian Congo and Brazil. *E. citriodora* responds readily to cultivation, and this is the only way in which regular production of oil may be achieved. *E. citriodora* is by nature a timber-producing tree, and, therefore, it has to be specially pruned if abundance of foliage is required for oil; otherwise the young tree shoots up to produce a robust trunk with a minimum of foliage. The oil of *E. citriodora* is distilled from natural

stands in Queensland and contains from 65–85% of citronellal. The oil is used for perfumery purposes and as a source of citronellal for the manufacture of citronellol, hydroxycitronellal and menthol.

Tea-Tree Oils. *Leptospermum citratum* Challinor, Cheel and Penfold is a tall shrub or small tree growing in somewhat inaccessible parts of eastern Australia and is very sparsely distributed. Production of the oil is spasmodic, but the oil, nevertheless, is of considerable commercial importance. Apart from limited quantities produced in Australia, the bulk of the oil of commerce is produced from plantations established in Kenya Colony and Guatemala. The leaves and terminal branchlets yield from 1 to 1.5% of an oil containing 75–85% of the aldehydes citral and citronellal in the proportion of 45–50% citral and 35% citronellal. The oil is highly prized as a source of pure citral, for, with the possible exception of the aldehyde obtained from the oil of *Backhousia citriodora*, it has no superior in the quality of its aroma. The oil has been used as a fortifier or modifier in perfumes where citral-containing oils are employed. It is also used in the production of essences for aerated waters.

Backhousia citriodora F.v.M. is a medium-sized tree with bright green leaves and small white flowers, which is found very sparsely distributed in Queensland. The leaves and terminal branchlets yield about 1% of essential oil consisting almost entirely of citral (95%). It was first described by the firm of Schimmel & Co. of Miltitz, Germany, in 1888. The citral isolated from this oil is of superlative quality. Unfortunately the stands of this tree occur in restricted belts in the rain forests (brush) between Brisbane and Rockhampton, Queensland.

Small quantities of the oil have been distilled and marketed spasmodically during the past 60 years. Consequently it has had a chequered commercial career, owing to the inability of distillers to maintain continuity of supply. Attempts to establish plantations have not been successful, as it is a relatively slow grower compared with other citral-bearing plants.

Boronia Flower Oil. *Boronia megastigma* Nees. The flowers of this graceful Western Australia shrub ("brown" boronia) which possess a delightful fragrance have been used in the manufacture of a concrete otto for many years past. Unfortunately the spread of population and the advent of modern air travel, whereby flowers have a higher value for floral purposes than as a source of raw material for perfume, have caused the product almost to disappear from the Australian market. There is, however, a limited demand for the concrete otto from France where this particular type of perfume is greatly valued for certain special creations of the perfumer's art.

The yield of concrete is influenced by seasonal factors, and yields of 0.4% to 0.8% have been recorded. One return showed that 1000 lbs. of blossoms after extraction with petroleum ether yielded 66 lbs. of concrete, of which 60% was absolute.

The most important odorous constituent of *Boronia* flower oil is β-ionone which was isolated and identified by Penfold in 1927. This was the first recorded occurrence of this ketone in nature. The oil has since been critically examined by other workers, and the presence of α and related ionones has been established.

Australian Sandalwood Oil. *Eucarya spicata* Sprag. and Summ. is a diminutive tree or large shrub of straggly habit, 12 to 20 feet in height, with a trunk six to ten inches in diameter. It occurs in the arid regions of Western and South Australia. The roots and butts are used for the production of Australian sandal-

wood oil. The oil was first distilled experimentally in 1875 by Schimmel & Co. of Leipzig, Germany. It is difficult to determine exactly when Australian sandalwood oil was first placed on the market. However, over 50 years ago there was sporadic production of the oil by a number of small distillers in Western Australia. It was not until 1921 that systematic production and scientific control of the oil were instituted by Plaimar Ltd., of Western Australia. Australian sandalwood oil has since been marketed for its santalol content in competition with the well-known East Indian sandalwood oil of commerce. Unfortunately continuous demand for the wood over the years has greatly reduced the existing stands, for production of the oil in Australia has declined greatly since World War II. This is due to the large number of logs exported to the Far East for incense purposes, coupled with the high cost of the wood through sandalwood cutters having to travel long distances for supplies. The main use of sandalwood oil today is in the perfumery trade. The demand for medicinal purposes has receded considerably since sandalwood oil was removed from the principal pharmacopoeias, although small quantities are exported to Malaya for self-medication. Total production of sandalwood oil in Australia of recent years has been below 10,000 lbs. per annum.

There is a possibility that the demand for the Australian oil might be increased through the recent discovery of farnesol as one of its previously unidentified alcoholic constituents.

Endemic Oils of Potential Economic Value

In addition to the oils already described, there are numerous Australian essential oils which are not yet in commercial production because (a) insufficient stands are available for continuity of supply to be assured, and (b) they are unable to compete in price with the oils from other well-established commercial species. Nevertheless it can be predicted that some of the oils about to be described will become available in the not far distant future, particularly if commercial plantations are established. The undermentioned oils are considered to be the most promising:

Backhousia citriodora var. " A ". A Queensland distiller of the oil of *Backhousia citriodora* noticed a slight difference in the odour of one of the distillates. The oil on investigation was found to consist of *l*-citronellal (62-80%), δ-isopulegol, citronellol and its acetic acid ester. The high optical activity of the citronellal is noteworthy; in addition, it is the first time this laevorotary aldehyde has been observed in an Australian essential oil.

The oil from the foliage of this tree is in marked contrast to that obtained from the leaves of a " type " tree containing 90–95% of citral. Subsequent investigation in the area under exploitation showed the trees to be in two pockets, each containing about a dozen trees, of which six or seven were variants and the remainder normal. All the trees examined were found to be morphologically indistinguishable from one another, and for the purpose of identification the variant or physiological form is called var. " A ". The oil from this tree is considered to be an unsurpassed source of high laevorotary citronellal (a_D-14.21°) for the manufacture of menthol.

Eremophila mitchelli Bentham. The wood of this " bastard sandalwood ", or " Buddah ", yields 3% of a reddish-brown oil consisting almost entirely of three crystalline sesquiterpene ketones—eremophilone, 2-hydroxyeremophilone, and 2-hydroxy-1:2-dihydroeremophilone. This small but potentially valuable tree is widely distributed throughout the drier areas of New South Wales and

Queensland. It is a matter for regret that it is exploited principally for firewood, although considerable quantities have been exported to the East for incense under the name of " rosewood ", where it has been used as a substitute for genuine sandalwood. The ramifications of the sandalwood industry have no doubt militated against commercial utilisation of its essential oil. The wood will no doubt come into its own when the existing supplies of sandalwood become exhausted. The oil has been shown to possess marked blending and fixative properties, but it has not yet been exploited for this purpose.

Eucalyptus australiana Baker and Smith var. " C ". In this particular form of eucalypt, cineole and *a*-terpineol have been replaced with *l*-piperitone and *l*-*a*-phellandrene. The oil in its physical and chemical characters is barely distinguishable from the oil distilled from *E. dives* " type ". Its exploitation is retarded on account of the large areas of *E. dives* " type " which are still available for distillation.

E. citriodora var. " A ". The oil of *E. citriodora* containing 65–85% citronellal has been marketed for many years, but quite recently trees were detected which yielded oils in which the citronellal had been largely replaced by its equivalent of citronellol and its esters. Unfortunately the number of trees whose foliage yields essential oils rich in citronellol and its esters is very small, and it will be necessary to establish plantations if the oil is to become a commercial product. This is one of the trees that is being studied in our own experimental plantations. As citronellal is used principally in the manufacture of synthetic citronellol, it would be of considerable economic importance if this conversion of the aldehyde into alcohol could be performed by nature instead of in the factory. The variant rich in citronellol and its esters has been named Variety " A ".

E. numerosa Maiden var. " A ". Here again we have a eucalypt yielding an oil similar in chemical composition to *E. dives* " type " and *E. australiana* var. " C ". Its exploitation is temporarily retarded, owing to the large areas of *E. dives* " type " and *E. australiana* var. " C " which are still available.

E. staigeriana F.v.M. This " lemon-scented ironbark " is another eucalypt which merits cultivation, as its essential oil possesses marked commercial possibilities. The oil was first examined by Schimmel & Co. of Miltitz, Germany, in 1888, and subsequently by Baker and Smith (1906). *Eucalyptus staigeriana* is sparsely distributed and is practically confined to the Palmer River district of North Queensland. The dried leaves and terminal branchlets of this small tree yield from 2.5% to 3.75% of an essential oil containing 16–60% of citral, the remainder consisting principally of laevo-limonene, geranyl acetate and sesquiterpenes. This tree is also being studied in the experimental plantations of the Museum of Applied Arts and Sciences, Sydney. Incidentally the tree has been successfully cultivated in Guatemala, and a sample of the oil examined by us in 1933 contained 56% of citral.

Leptospermum citratum var. " B ". As mentioned earlier in this paper, the oil of *Leptospermum citratum* " type " contains 75–85% of the two aldehydes citral and citronellal. Field surveys revealed the occurrence of plants whose foliage contains relatively small amounts of the two aldehydes, but the major constituents were found to be citronellol and geraniol with the corresponding acetic acid esters, i.e., the aldehydes citral and citronellal have been largely replaced by the corresponding alcohols and esters. The oil of the variant has a particularly sweet rose-like note, hence the desirability of developing this physiological form commercially. This form, known as var. " B ", is another oil-yielding

plant which is being studied in the experimental plantations of the Museum of Applied Arts and Sciences.

Melaleuca viridiflora Gaertner is a large tree known as the "broad-leaved tea-tree" which is widely distributed along the eastern coastline of Australia, from Port Jackson in the south to the Gulf of Carpentaria in the north, and extends to New Caledonia. The leaves and terminal branchlets yield from 1–2.6% of oil which consists of cineole (46–60%), various terpenes, α-terpineol, sesquiterpenes, etc. Except in New Caledonia, where the oil is exported under the name of "niaouli", it is of little commercial value, for it is unable to compete with the cajaput oil of commerce derived from *Melaleuca minor* Sm.

The oil of *Melaleuca viridiflora* has been noted for the uniformity of its chemical composition, but recent investigations have revealed physiological forms with oils consisting largely of the alcohols linalool and nerolidol. The oil obtained from trees growing in Queensland contains about 50% of each of these alcohols, whereas the oil distilled in New South Wales contains 30% linalool and 70% nerolidol. Here again establishment of plantations of this physiological form called var. "A" is imperative if Australia is to have a satisfactory source of supply of two such valuable perfumery isolates.

Melaleuca bracteata F.v.M. "type" and physiological forms. This tree, commonly known as the "black tea-tree", occurs in small stands in New South Wales and Southern Queensland. The leaves and terminal branchlets yield from 0.4 to 1% of a light amber-coloured oil, heavier than water, consisting mainly of methyl eugenol. The oil is a promising source of this phenol ether, both for perfumery purposes and as an insect repellent. It had not previously been considered for commercial purposes whilst Huon pine wood oil was available in large quantities. Huon pine wood oil has recently disappeared from the market and an alternative source of methyl eugenol is urgently required. Consequently experimental plantations of *Melaleuca bracteata* are being established for the purpose of obtaining high-yielding strains for commercial plantations. Two physiological forms have recently been observed, the oils of which contain from 80–95% of methyl iso-eugenol and elemicin, respectively, the methyl-eugenol of the type being completely replaced. The separate and single occurrence of different phenol-ethers as major components, without admixture with each other and derived from individual trees of this species is a matter of considerable biological and economic significance.

Exotic Oils

Many attempts have been made during the past 50 years to establish areas of lavender and peppermint in Australia, but, with one single exception, without success. There are two reasons for the failure: (a) the difficulty of acquiring selected stock, and (b) the inability of the Australian produced oil to compete in price with oils imported from England and Europe. However, since 1922 small quantities of lavender oil have been successfully produced at Lilydale in north-eastern Tasmania. The oil is of very good quality with a high ester content. No reliable figures of production are available, but the area in question, reported to be over 200 acres in extent, produces a very fine oil of the French type.

Both peppermint and spearmint have been under trial for many years in the various experimental farms of the New South Wales Department of Agriculture, as well as in sporadic attempts by commercial interests. It is only quite recently that the establishment of peppermint in Australia has been seriously con-

sidered. The plantations will probably be established in N.E. Tasmania.

It is important to remember that the failure to establish exotic oil-yielding plants on a commercial scale in Australia has been due in great measure to high costs of land and labour which have rendered production of oil uneconomic.

Research

The first systematic investigations into the oil-yielding flora of Australia were initiated by Messrs. Baker and Smith in 1896. The results of their investigations were published in two monumental works entitled " A Research on the Eucalypts especially with regard to their Essential Oils ", and " A Research on the Pines of Australia ". The " Research on the Eucalypts " was published first in 1902, and a revised edition in 1920. These investigations have been continued by Penfold and his associates during the subsequent 30 odd years. Baker and Smith in their classic collaboration were the first investigators to use chemistry as a means of differentiating species which showed very slight botanical differences.

These extensive investigations, which have been continued without interruption for nearly 60 years, have exerted considerable influence on the development of forest products in Australia and have led to:

(a) the establishment of the eucalyptus oil industry on a scientific basis,

(b) the production of non-corrosive and non-poisonous germicides, using eucalyptus and " tea-tree " oils in lieu of coal tar products, and

(c) the isolation of a number of new substances of great scientific and technical interest. Some of the constituents of Australian essential oils are as unique as the flora itself, and are without parallel in the chemistry of plant products.

For over 50 years the scientific investigations on the essential oils of the Australian flora had led to the exploitation of a number of oils and their derivatives. On the other hand, it was felt that the development of the essential oil industry had not made the progress that might have been expected. The decision was made in 1945 to apply the accumulated scientific findings to investigations which could meet the rapidly changing world conditions. The long-range policy, which is now in operation, and which will influence future investigations, is briefly as follows:

(a) To utilise our accumulated knowledge on the chemistry of essential oils to determine their actual role in the metabolism of the oil-yielding plants of Australia by experiment in place of speculation.

(b) To find practical application for some of the unusual constituents, such as β-diketones: angustione, dehydro-angustione, leptospermone, calythrone; and the sesquiterpene ketones: eremophilone, hydroxyeremophilone and hydroxydihydro-eremophilone; cryptone (a nine carbon ketone), croweacin (a phenol ether) and lanceol (a sesquiterpene alcohol)

  (a) As raw materials for the manufacture of other useful products, or as new substances for further fundamental researches, and

  (b) Their value in pharmacology.

(c) To develop methods for controlling the composition of the essential oils of oil-yielding plants, and using these techniques for the subsequent development of entirely new varieties of oil yielding plants. Work on the selection and breeding of special varieties of oil yielding trees is at present confined to: *Eucalyptus polybractea*, *E. australiana*, *E. dives* " Type " and Var. " C ", *E. macarthuri*, *E.*

citriodora, Leptospermum citratum, " Type " and Var. " B ", *Melaleuca alternifolia, M. viridiflora* and *M. bracteata.*

Present and Future Status of the Industry

The Australian essential oil industry, in common with the majority of primary products, fluctuates from time to time in accordance with prevailing economic conditions. These fluctuations are often of a violent nature, seeing that more than 70% of the Australian production is exported. Competition in eucalyptus oil during the boom of 1951 and the early part of 1952 forced prices to such a high level that it became uneconomical for other countries to buy our oil. This was in keeping with the world-wide trade recession which caused production to be severely curtailed. Other countries, like our own, were forced to restrict their imports, and there were indications that most importing countries were probably holding fair stocks in reserve. This resulted in almost complete cessation of exports in the first half of 1953, when the economic situation began to improve. There is now every indication that by 1954 production will again reach the figures attained in 1951–52 and 1953–54.

An additional factor has been the increased production of eucalyptus oil by countries which have established plantations from seed imported from Australia. This has enabled producers in foreign countries with lower labour costs and easier access to the world's markets to under-sell the Australian product.

The eucalyptus oil industry in particular received a marked fillip when prices were fixed at the point of production by the Commonwealth Prices Commissioner in 1943. This resulted in prices rising to unprecedented heights compared to those ruling before 1939. For example, *E. dives* " Type " rose from 1/- per lb. to 4/6 per lb. It should be emphasized, however, that it was not until prices were fixed at the point of production that distillers were able to make a decent living. It gave a stability to the industry that had not hitherto existed. There was a recession during 1952, which gave a desirable respite to cutting, for high prices invariably result in rapid depletion of forest stands.

Australian medicinal eucalyptus oils containing 70% cineole have been meeting strong competition from Spain, Portugal and Brazil on the overseas markets for some considerable time. It was in order to meet this competition that experimental plantations were established for the purpose of developing varieties of *Eucalyptus* and other essential oil-yielding trees with higher yields of both oil and principal constituents than those obtained from naturally occurring trees. The day can be foreseen when there will be a considerably reduced market for oils rich in cineole, and therefore researches have been initiated for the purpose of using cineole as a raw material for the manufacture of more valuable substances.

Until recently we were content to export the various crude oils, even some of the seeds of our *Eucalyptus* and " tea-tree " species, with the result that Australia was becoming essentially a supplier of raw materials.

Our objective is to market such important essential oil isolates as citral, citronellal, citronellol, geraniol, geranyl acetate, piperitol, elemicin, methyl eugenol, methyl iso-eugenol, linalool and nerolidol in lieu of the crude essential oils.

The future of the industry depends largely upon the extent to which new areas are developed, but more particularly upon the conservation of the principal oil-yielding species. Vast areas of oil-yielding flora have been totally destroyed to provide grazing areas, mainly for sheep. The clearing of land in this way, particularly if the stumps are de-

stroyed, often results in serious damage to the countryside through erosion. Despite the fantastic prices paid for wool during the past few years, there are certain areas of *Eucalyptus* country which have proved to be more profitable under oil-yielding eucalypts than when used for grazing sheep and cattle.

Competition from overseas producers will best be met by the establishment of commercial plantations based upon selection and breeding of special varieties of essential oil-yielding plants being carried out by the staff of the Museum of Applied Arts and Sciences, Sydney. An effort is being made to grow eucalypts as an agricultural crop instead of as a forest product. At the same time natural stands of eucalypts can be considerably improved by cutting out the non-oil species or other non-productive forest growth, and filling in the gaps with nursery grown seedlings of good quality. This practice is being gradually adopted in various parts of Australia.

Selected Bibliography

Baker, R. T., and Smith, H. G. A research on the eucalypts especially in regard to their essential oils. 2nd Ed. (Tech. Educ. Ser. No. 24). Govt. Printer, Sydney. 1920.

Blakely, W. F. A key to the eucalypts. The Worker Trustees, Sydney. 1934.

Guenther, E. The essential oils. 6 vols. 1948–52.

Maiden, J. H. A critical revision of the genus *Eucalyptus*. 8 vols. Govt. Printer, Sydney. 1909–33.

Penfold, A. R., and Morrison, F. R. Commercial eucalyptus oils. 5th Ed. (Mus. App. Arts and Sci. Bull. No. 2). Govt. Printer, Sdyney. 1951.

Penfold, A. R. The volatile oils of the Australian flora. Liversidge Lecture, delivered to the 27th meeting of the Australian & New Zealand Association for the Advancement of Science. Govt. Printer, Tasmania. 1949.

Utilization Abstracts

Indian Oilseeds. Only 5% of India's cottonseed is pressed for oil. That country's vegetable oil shortage could be alleviated not only by greater use of cottonseed but also by extraction of oil from other seeds not yet processed for that purpose, namely, those of kamala (*Malotus philippinensis*), tobacco, poppy, perilla, candlenut, stillingia, hemp, walnut, nim (*Melia indica*), *Pongonia glabra, Calophyllum inophyllum, C. wightianum* and pisa. (J. S. Aggarwal, *Jour. Oils & Oilseeds 5(10/12): 19. 1953*).

Indians' Berries. Thimbleberries, salmonberries, blackberries, dewberries and cranberries all played a part in the economy of the Indians and pioneers in the American Northwest. "Along the coast there were cranberries, *Oxycoccus oxycoccus*, in the sphagnum bogs. In the swamps of the coastal mountains the western blueberry, *Vaccinium uliginosum*, was hunted. Red whortleberries, *Vaccinium parvifolium*, were rather generously scattered over the Northwest in lower elevations. These were picked by coastal and interior tribes. A blue whortleberry, *Vaccinium ovalifolium*, grew in the deep woods of the coast range and they were the most sought after of all coastal berries".

"The tribes of the interior valleys and the Cascade Range did not have as many varieties of berries, but they had more dense blueberry fields in which to pick. Their favorites were the mountain bilberries, *Vaccinium membranaceum* and *Vaccinium deliciosum*".

These uses have continued with the present day descendants of the aborigines, but modern roads and city markets have intruded upon the berry-picking areas of the Indians. As a result, friction has at times developed between the surviving Indians and the berry-hunting white man. In one area, at least, the Gifford Pinchot National Forest in Washington, the conflict was settled by a "treaty" which gave the Indians the exclusive right for all time to pick berries in three areas of their own choosing in the Forest. "In their exclusive 'treaty' area near Mt. Adams, the Indians harvested nearly $40,000 worth of berries in 1951", and "it is estimated that they harvest around $10,000 worth of berries in the Mt. Hood National Forest each year". (W. H. Osborne, *Nature Magazine 46(9): 482. 1953*).

The Natural Origins of Some Popular Varieties of Fruit[1]

While the skill of plant breeders, by their techniques of artificial hybridization, have produced many valuable varieties of edible fruit, other important varieties have arisen by natural hybridization and mutation without the assistance of man. Among them are the Concord grape, Washington navel orange and pink grapefruit.

ERSTON V. MILLER

Department of Biological Sciences, University of Pittsburgh, Pittsburgh, Pennsylvania

Plant breeders have given to the farmer and home gardener a number of varieties of fruits, flowers and vegetables which are radically different from original types. In many instances dwarf varieties are available to the amateur with limited space for planting, whereas the commercial grower, who is primarily interested in larger yields, has recourse to types which produce bigger and better crops as the result of hybrid vigor. Double blossoms have largely replaced single flowers in border planting, and one may have blue roses and pink African violets if he wishes. Small fruits, like the strawberry and raspberry, have been bred to suit any clime in the United States so that successful production need no longer be restricted to a limited region. Another area in which the plant breeder has been successful is in the production of strains of plants which are resistant to specific diseases.

The object of this paper is not to discuss the excellent work of plant breeders, but rather to relate a few stories regarding varieties of fruits which have been given to us by nature, in many instances antedating the plant hybridizer. Sometimes the new type has arisen from a seed which was planted by a grower who knew nothing of the seed's ancestry. He merely planted a seed and "took a chance". In other instances the new fruit has been discovered on a tree which was believed to be a seedling, perhaps found on a farm or growing "wild". The latter is sometimes referred to as a "wilding". In all cases the new variety appeared by chance, without its discoverer having had any part in pollination or hybridization or in any other manner planning its parentage.

Then there is the "bud sport". Sometimes flower buds on a single branch of a tree will bear fruits which are quite different from those produced on other parts of a tree. The new fruits may be seedless, they may have a different internal or external color, they may mature earlier or later, or they may be larger or smaller. These are bud sports. It is a characteristic of the whole branch which bears these fruits, as indicated by the fact that leaf-buds instead of flower-buds may be removed and inserted into the bark of another tree of the same species, and the "bud wood" will grow and produce fruits identical with those of the original bud sports.

Concord Grape

Most of us are no doubt familiar with this attractive blue variety of grape that makes its appearance on the markets in

[1] An expansion of an article which appeared under the title "Our Heritage of Good Fruits" in The Scientific Monthly 77(1): 42–48. 1953.

early fall. It is the most widely grown grape on this continent and with its offspring, both pure-bred and cross-bred, represents 75 percent or more of the grapes of eastern America. Here is how it started.

The early American colonists attempted to introduce European grapes into this country from the very begining of colonization. Grapes which they brought with them were the Vinifera or wine-grape type, such as is grown extensively in California at the present time. Attempts at wine production or, more properly, production of wine grapes, were made not only to please the palates of the colonists but also to create an industry for the colonies. So for 200 years experiments to grow wine grapes were made in all parts of the eastern United States, and for 200 years the experiments failed. It is now known that European grapes failed to grow in America because of attacks by the *Phylloxera* insect, mildew rot and other native parasites to which the native American grapes are comparatively immune.

It seems that for a long time it never occurred to the early colonists to attempt to cultivate the wild native grapes. It is true that wild grapes were small-fruited for the most part and full of seeds; but the Indians utilized them. Eventually, however, the colonists began cultivating native species of grapes. John Larson, a Scotch engineer, spent eight years, beginning in 1700, in exploring and surveying North Carolina. He reported six kinds of wild grape, three of which had been moved to gardens.

Two important events occurred in 1852 which tended to revolutionize grape-growing in America. The first of these was the production of hybrids between American and European grapes. The second event was the introduction of the Concord grape. It is this second event with which we are concerned. In the fall of 1852 E. W. Bull, of Concord, Massachusetts, exhibited a seedling grape at the meeting of the State Horticultural Society. The seedling was named the " Concord ". Bull had planted the seed of a wild grape in his garden, and it bore fruit in 1849. The wild grape, from which the seed had come, had been transplanted to the garden from beside a field fence.

Other than this, the actual ancestry of the Concord is not known. The botanical characters, according to Hedrick, indicate that it is a pure-bred Labrusca (Fox grape), although some are of the opinion that it is possibly a Labrusca-Vinifera hybrid. A Catawba grape vine was growing in the garden at the time that the Concord was discovered, and it is possible that the Catawba vine may have fertilized the seed from which the Concord grape was produced.

The new grape was introduced by Hovey and Company of Boston in the spring of 1854. From the time of its introduction its growth was phenomenal. Within a year its culture spread halfway across the continent. In 1865 the Concord grape was awarded the Greeley prize by the American Institute. Horace Greeley, the donor of this prize, considered the Concord the best grape for general cultivation and called it the " grape for the millions ". When one realizes that there were no other " juice " grapes at that time, it is not surprising that the Concord made such a hit. Even today this grape is one of the most popular varieties. There are better grapes in some respects, but they cannot be produced as cheaply as the Concord and must take second place from the standpoint of commercial production.

Two other table grapes appear on the market at about the same time that the Concord is offered for sale. These are the large, green or white, Niagara, and the small, pink-fruited Delaware. Niagara is a known cross between Concord

and Cassady, produced by C. L. Hoag and B. W. Clark of Niagara County, New York. The Delaware, however, belongs in our story because its origin is unknown. It was brought to the notice of the Ohio Pomological Society in 1851. It was traced to the garden of Paul H. Provost, a Swiss of Frenchtown, New Jersey. One story says it came from a brother residing in Italy; another that it was brought to Provost's place by a German. It could have grown up in the garden as a seedling.

Other Small Fruits

The origins of some of the other small fruits may not be so dramatic as that of the Concord grape, but many of them were chance seedlings or wildings or bud sports, and they serve to substantiate our claim that nature provided generously until man took over. For example, a very popular red raspberry, the Cuthbert, originated as a chance seedling in 1865. This is a large-fruited variety with a delectable flavor and aroma. Golden Queen is a bud sport of Cuthbert. It has been referred to as the only yellow raspberry which is worth planting. Golden Queen is more cream colored than yellow, and it retains all the flavor of the Cuthbert.

Most of the old standard varieties of black raspberries, such as the Cumberland, are supposed to have originated as seedlings. The same is true of one of the most popular purple varieties—the Royal Purple. Likewise many of the older varieties of commercial blackberries originated by chance. Eldorado, Blowers, Agewam, Early Harvest and Mersereau were either seedlings or wildings.

Perhaps more new varieties of strawberries than any other fruits have been introduced in recent years. In the past, however, we were dependent upon nature's productions for market varieties, many of which are still being grown commercially. A typical example is the Missionary strawberry which originated as a chance seedling in 1916 in Virginia. It practically "grew up" with the winter strawberry industry in Florida. For about 25 years strawberries were shipped from Florida to the northern States during the winter months, and for many of those years it was the Missionary variety that was shipped exclusively. Strawberries were among the first luxury winter fruits in this country.

Peaches

If one seeks a dramatic origin of a variety of fruit, he need not look beyond the peach industry. The year was 1870; the scene, Marshallville, Georgia. In this region peach trees are always at their best, as they grow with their roots deep in red clay and their tops reaching up toward clear blue skies. In the year just mentioned Samuel H. Rumph, a prominent peach grower, had a "Chinese Cling" peach tree on his farm. Fruits of this variety are best suited for canning or preserving. Two seeds from the fruits of this Chinese Cling tree made history. Mr. Rumph planted one seed and gave the other to his brother, L. A. Rumph. The first-mentioned seed produced the well-known Elberta peach. This is now the leading commercial variety, at least in the eastern United States. A large fruit with yellow flesh and usually red around the pit, the Elberta has graced many a fruit bowl. Since it is a late variety, it does not appear on the market until late summer, and it is marketed until frost.

Whatever became of the other seed of the Chinese Cling tree? Mr. L. A. Rumph, who also lived in Marshallville, planted his seed too. Strangely this produced the "Belle of Georgia". In the opinion of many, no better peach was ever discovered. The flesh is white and not quite so firm as that of the Elberta; flavor is indescribable and Hedrick has

spoken of this variety as " truly voluptuous in form and color ". Because of its tender flesh, Belle of Georgia will not stand the rigors of shipment to distant markets and is not able to compete with firmer varieties.

How did both a yellow and a white-fleshed variety originate from the same tree? Mr. Rumph stated that the Chinese Cling tree stood near Early and Late Crawford, Oldmixon free-stone and cling trees. Ample opportunity for cross-breeding existed so that each of the two seeds could have had different parents.

Other commercial varieties of peaches which originated as chance seedlings are J. H. Hale, Hale Early, Champion, Hiley and, in all probability, Early and Late Crawford.

Cherries

Many of our leading cherry varieties in this country have a rather mysterious past. Early Richmond, a popular sour cherry, is the old Kentish of England and may have been introduced into England by the Romans. A standard late sour cherry in America is the English Morello. Its origin is unknown, but it is believed to have originated either in Holland or Germany, whence it was introduced to England and later to France. By far the most popular sour cherry in this country is the Montmorency. It originated in the Montmorency Valley in France several centuries ago.

Of the sweet cherries, Napoleon is a leading firm-fleshed variety. It was grown by the Germans, French, Dutch and English early in the eighteenth century, but its history prior to that time is obscure. Another sweet cherry, Lambert, flourishes best in the northwestern part of the United States. This cherry originated as a seedling under a Napoleon tree about 1848.

Apples

Smock and Neubert, in their book entitled " Apples and Apple Products ", state that there are well over 1800 varieties. Not many of these, however, enter into commerce today, and, when considering only the most popular commercial varieties in the United States, the list can be reduced to 24. What is significant is that only one of these 24 has been produced by plant breeders. It is the Courtland which is the outcome of a cross between Ben Davis and McIntosh. All of the remaining 23 varieties have resulted either from chance seedlings or from bud sports, or the origin is unknown.

Rhode Island Greening and Winesap have been traced back to colonial days, but the exact origins of these apples are not known with certainty. The following story of the origin of the Rhode Island Greening apple appeared in the American Gardener in 1901, and, according to S. A. Beach, it is probably true. Near a place known as Green's End in the Vicinity of Newport, Rhode Island, there was in olden times a tavern which was kept by a Mr. Green. The proprietor of this tavern raised apple trees from seed. One of his seedling trees bore large green apples which were greatly admired by people who stopped there as guests. In fact many requests for propagating material were received. There was such a demand for scions from this particular tree that it subsequently died from excessive cutting and exhaustion. In Rhode Island the fruit which was produced as the result of grafting with these scions was called the " Apple from Green's Inn ". In nearby States it was known as " Green's Inn Apple from Rhode Island ". It does not require much imagination to infer that the present name of Rhode Island Greening is merely a corruption of one or the other of these early names.

The following varieties of apples were " found " and in all probability were chance seedlings: Delicious, Esopus of Spitzenberg, Grimes Golden, Jonathan, Rambo, Smokehouse, York Imperial.

Space does not permit elaborating on the circumstances surrounding the discovery of all these varieties; so let us limit ourselves to one—the York Imperial.

The York Imperial apple originated on a farm adjoining what was then known as the Borough of York, Pa. The owner, a Mr. Johnson, noticed that schoolboys came to a certain tree in early spring to get the apples which had passed the winter on the ground, covered by leaves. Mr. Johnson found the fruit in very fine condition, and when the next crop matured he took samples to Mr. Jonathan Jessop, a local nurseryman, who began propagating this variety under the name of "Johnson's Fine Winter". This was before 1830. Sometime later Charles Downing pronounced this apple the "imperial of keepers" and suggested the name York Imperial. The trees did not sell very well at first and Mr. Jessop dumped his surplus trees into a hollow beside the turnpike which passed his nursery. Farmers, returning from market, picked up these trees and planted them on their own farms in the lower end of York County. After its merit as a commercial variety was established, the York Imperial apple became widely distributed throughout Maryland, Pennsylvania and Virginia, and soon was a leading market variety in these States.

The York Imperial is characterized by firm flesh and is usually considered a cooking apple. It holds up well in cold storage (as was discovered by the school boys described above) and is sometimes welcomed as a dessert apple late in spring when softer-fleshed varieties are no longer available.

Pears

Most of our popular pear varieties have come to us from Europe. Bartlett, which leads all other varieties in America in number of trees, came from England and is there known as Williams. A schoolmaster from Berkshire discovered this pear as a wilding and brought it to America in 1797 or 1799. Bartlett is a large, light-yellow pear and is the first to appear on our markets in summer.

Continental origin of several other pears is evident from either their present or original names. Anjou (originally Beurre d'Anjou) is an old French pear with origin unknown. It is an excellent fall variety with a slightly astringent "tang". Comice (Doyenne du Comice) originated as a seedling. Beurre Bosc (now called Bosc) and Winter Nellis were both raised from seed in Belgium.

Our first typically American pear was the Seckel. Most of us remember this small, sweet, red-cheeked pear from our school days. Six or eight of the small fruits could be carried in a pocket at one time. The story of the origin of the Seckel pear is as unique as that of any other thus far unfolded. Toward the end of the eighteenth century there lived in Philadelphia a well-known sportsman and cattle dealer. He was known by the name of "Dutch Jacob". Each autumn Dutch Jacob would bring exceedingly delicious pears back from his hunting trips and would distribute them to his neighbors. The exact location of the pear tree was known only to the huntsman. Soon a tract of land south of Philadelphia was sold in parcels and Dutch Jacob was one of the purchasers. As a result of his purchase he became the owner of the land where his favorite pear was growing. This was near the Delaware River. The land subsequently became the property of a Mr. Seckel, who gave the pear its present name. What about the origin of the pear? Your guess is as good as mine.

Plums

In a brief article of this type it is not possible to do justice to the topic of plums because, in the first place, 2000 varieties, from 15 species, are now or have been under cultivation. In the second place the varieties which are avail-

able today may have come from any one of three sources—Europe, the Orient, or from species of wild plums which are native to North America. Let us be content, therefore, as we have with the other fruits, to relate one or two interesting stories which will illustrate our point. In fact we might limit ourselves to a discussion of plums which originated in this country because information on the origin of varieties introduced from the Old World is usually buried with the past.

The first native plum to receive a varietal name was the Miner. In 1814 William Dodd, an officer under General Andrew Jackson, planted a plum seed in Knox County, Tennessee. Dodd was not certain whether this seed came from a batch which he had gathered during the previous year on the banks of Talaposa Creek, or whether it came from a lot given him by an Indian Chief. Whatever the case, the seedling bore good fruits and the variety was known either as General Jackson or Old Hickory. Throughout the ensuing years the varietal name was changed a number of times. For instance, it was next called William Dodd and Chickasaw Chief. Dodd's brother moved to Galena, Illinois, taking some of the plums with him, and the variety then became known as Hinchley. How it acquired the name of Miner is not clear, although it probably took its final name from a Mr. Miner who grew and disseminated this plum in the State of Pennsylvania.

Although the Miner plum was the first of the native plums to receive a varietal name, another, the Wild Goose plum, was the first to be generally grown as a distinct variety. The story of the origin of this plum has been told with a number of variations. According to the one which is reported by Hedrick, who admits that it is " more romantic than credible ", M. E. McCance shot a wild goose on his farm near Nashville, Tennessee. His wife, in dressing the goose, found a plum seed in the craw. This seed was planted in the garden, and the tree which grew from it subsequently bore fruit of high quality. It was quite natural, therefore, that this plum should be called the " Wild Goose plum ".

Washington Navel Orange

In 1896 the Reverend F. J. C. Schneider, the first Presbyterian missionary to Bahia, Brazil, wrote to the U. S. Commissioner of Agriculture, telling him about an orange, grown locally, which might have commercial possibilities in the United States. This was the Navel orange. It probably originated as a bud sport. At any rate the orange appears to have been propagated between 1810 and 1820 by a Portuguese who lived at Cabulla, a suburb of Bahia, Brazil. It was here that the Reverend Schneider first saw it.

After an unsuccessful attempt to ship bud-wood to the United States, a shipment of 12 budded trees was forwarded to the U. S. Department of Agriculture in Washington, D. C. They arrived in good condition in 1870. Other trees were propagated from these, and two of them were sent to Mrs. Luther C. Tibbetts, in Riverside, California. Mrs. Tibbetts grew the trees in her backyard. It is from these two trees that the Navel orange industry of California, and mainly of the whole world, has developed.

This Navel orange has had a number of " first " names. After its introduction into the United States it was called the " Bahia Navel ". Later it acquired the name of the " Washington Navel " because of its having been propagated first in Washington, D. C. Next it was the " Riverside ". Now it is once more called the " Washington Navel " by horticulturists, although tradespeople usually refer to it as the California Navel orange. This is not surprising, since California supplies most of the navel oranges which we see in our markets.

Florida-grown Navel oranges are quite popular with the frozen- or cold-section trade. Fruit sections are peeled for salads and shipped in gallon containers to the larger markets.

Seedless Grapefruit

It is strange how we show a preference for seedless varieties of fruits. The fruit merchant, realizing this, usually advertises his " seedless grapefruit " with large placards; but if he is selling the Duncan " seedy " type, he is more than likely to avoid any reference to internal quality. The housewife, too, prefers to serve seedless grapefruit. What if the seedy types of grapefruit do possess better quality—more sugar, more vitamins, more minerals—than the seedless type? It seems that most of us still do not like to cut out seeds before serving, and therefore, because of its seedlessness, the Marsh grapefruit eclipses all other varieties.

In 1862 William Hancock, of Socrum, near Lakeland, Florida, purchased a farm from one Mrs. Rushing who is credited with having set out three seedling grapefruit trees. One of these trees bore seedless fruits and thus became the parent of the Marsh Seedless. Budwood was purchased by E. H. Tison, a nurseryman, who subsequently sold his nursery to C. M. Marsh, another nurseryman. The latter then marketed it as the Marsh seedless grapefruit. It is believed by some that the Marsh grapefruit originated from a " root-sprout " of an old tree which normally produced seedy fruits. Others still adhere to the theory that this variety originated as a seedling. Whatever the case, the Marsh grapefruit is now grown extensively in Florida, Texas, California, Arizona, South Africa, Israel, Australia and South America.

Pink Grapefruit

At Manavista, on the Gulf Coast of Florida, may be found the Atwood Groves. If nothing unusual had ever happened to these groves they would still be famous because of the fact that the rows of grapefruit trees are a mile long. But something more important did happen in this grove.

In the citrus season of 1906–07 R. B. Foster was foreman of the Atwood Grove. Mr. Foster was sampling grapefruit, and when he cut open a certain one, he found to his surprise that it was pink. Other fruits on this one branch of the tree were also pink. *One branch on one tree in a grove of thousands of grapefruit trees bore pink grapefruit.* It is not surprising that Mr. Foster marked this particular branch with a large " P " (to indicate pink) in order that he might not miss it when returning. It should be mentioned that the original tree on which the pink-fleshed fruit was discovered was the Walters variety, a pale-fleshed, seedy fruit. This newly discovered pink grapefruit was therefore seedy too.

In 1913, in the Thompson Groves at Oneco, Florida (not far from the Atwood Groves), a bud sport was found in a Marsh seedless tree. The fruit in this case was pink-fleshed and seedless. Thus originated the Thompson Seedless grapefruit.

The trees of Thompson (or Pink Marsh) grapefruit were sold to Albert E. Henninger of McAllen, Texas, in 1926. In 1929 a new red-fleshed variety originated as a bud sport on one of these Thompson trees in Texas. Henninger called this new sport the " Ruby " and obtained a patent on the fruit. This was the first citrus fruit to be patented. The Ruby grapefruit is grown extensively in Texas, and it is mistakenly believed by many that all pink-fleshed grapefruit originated in that State.

Temple Orange

No connoisseur of citrus fruits speaks of quality in oranges without mentioning the Temple variety. More and more this particular orange is becoming a

familiar sight on the markets—deep orange in color, oblate to spherical, the peel slightly pebbled. To the layman it is often a " kid-glove " orange, for there is much in it that resembles the tangerine. The aroma and flavor of the orange-colored flesh can be described only as superlatively delicious—for want of a more descriptive term.

" Original " Temple orange trees have been located in Winter Park and in Oviedo, Florida. According to T. Ralph Robinson, these trees (and probably a number of others) were budded with budwood which had been brought in from Jamaica. Years ago the tree in Winter Park, which stood in the groves of L. A. Hakes, attracted the attention of D. C. Gillette, a nurseryman, who made arrangements to propagate the orange on a large scale. The fruit was named for William Chase Temple, a neighbor of Mr. Hakes. Mr. Temple had for many years been a citrus leader and President of the Florida Citrus Exchange. Between 1915 and 1925 Florida growers became very enthusiastic about the Temple orange, and by 1921 there were 10,000 acres planted to this variety. Unfortunately most of the early plantings were made with trees budded on rough lemon rootstock with the result that many of the fruits were coarse and developed dry segments before they matured. The quality of the fruit was so inferior for several seasons that growers became discouraged, and the reputation for this variety in the markets was almost ruined for all times. Fortunately the trees in a few groves had been budded on sour orange stock and had been planted in favorable locations. Fruits from these trees had all the fine quality that had previously attracted the attention of citrus experts to the Hakes tree. These observations led to the wide practice of budding Temple oranges on sour orange rootstock, and sometimes on Cleopatra Mandarin stock. Subsequently the trees on rough lemon rootstock produced better fruits as the trees became older and with the use of trace elements in the fertilizer. The Temple orange thus staged a successful come-back.

The characteristics of the Temple orange certainly suggest that it is a hybrid because it is part like a Mandarin, such as the Tangerine, and part like the common sweet orange. However, since it is susceptible to scab (and the sweet orange is not), it may have resulted from a cross between the Tangerine and the sour or Seville orange. But no Tangerine ever had enough sugar to overcome the acid normally found in a sour orange, so what tended to sweeten this offspring of the sweet and sour fruits, one will never know.

It is interesting to note that there is a limb on the original Temple tree in Winter Park which regularly produces " navel " fruits, that is, Navel Temples. This may account for the fact that many Temple oranges in commerce show a protruding navel, much like Washington Navel oranges.

Pineapple Orange

The Pineapple orange represents Florida's most popular midseason variety, reaching the market during the period from November to February. It is thin-skinned, usually deep orange in color, and its flesh possesses excellent flavor and texture. The fruit contains a large number of seeds, many of which have one end flattened. Here is the story of the Pineapple Orange.

Pioneer settlers at Charleston, South Carolina, or some other seaport, purchased sweet oranges which were brought in by ships from tropical countries. These fruits were called " China oranges ". The colonists planted seeds of these sweet oranges, and one of the pioneer settlers, Dr. J. B. Owens, brought nine of the seedling orange trees with

him when he moved from South Carolina to a place near Citra, Florida. Among the several sweet orange trees on the Owens place was one tree, the fruit of which seemed to resemble a pineapple fruit. The Owens family named this orange the Pineapple orange. P. P. Bishop, a Baptist missionary, organized a fruit-growing company in the same area and planted orange trees which were budded with budwood from the J. B. Owens farm. The Bishop interests discovered a superior strain of Pineapple orange in one of their hammock groves. The tree which bore these superior fruits was segregated and used for propagating material and was therefore the true original source of the present-day Pineapple orange.

The expression "sweet orange" is used to distinguish these fruits (*Citrus sinensis*) from the sour orange (*Citrus aurantia*) which was introduced by the early Spaniards. It is interesting to note that when the English settlers came to North Florida, pushing the Indians farther south to the Everglades, there were growing around what is now called Orange Lake, hundreds of acres of sour orange trees among the forest trees and bushes. In some instances citrus growers inserted budwood of the new Pineapple orange in the wild sour orange trees right where they stood in the hammock.

Such a planting can be seen today in a section of the Crosby-Wartman Groves at Citra. The late W. J. Crosby used to take great pleasure in conducting visitors to this portion of his grove where the random arrangement (instead of regular rows) of orange trees offered mute evidence that the rootstocks were the original wild orange trees which in all probability had been planted by the Spaniards or the Indians.

Many other common varieties of citrus fruits appear to have originated by chance. Among the oranges, Boone's Early, Parson Brown and Conner's Seedless originated as seedlings, and Hamlin and Enterprise are believed to belong in this category. The most popular Tangerine, the Dancy, began as a seedling. The same is true of the Eureka lemon which is the most extensively grown variety of lemon in California.

Gros Michel Banana

The banana appears so much at home in tropical America that perhaps many of us have assumed that this fruit originated in the Western Hemisphere. This, however, is not the case because bananas were introduced to the Americas by the Spaniards four centuries ago. It is assumed that the homeland of this fruit is the humid tropics of southeast Asia. At the time of its introduction in the New World, many types had been recorded and were being grown in suitable locations all around the equator. But the Gros Michel variety, the common, sweet, yellow banana on our markets today, had an accidental origin, just like many other varieties of fruits described in this article.

One day in 1836 Jean Francois Pouyat, a Jamaica planter, while strolling through farms in nearby Martinique, came suddenly upon a new kind of banana. He took it to his own estate, planted it and gave it the name of "Banana-Pouyat". The banana eventually became the Gros Michel, and thus began a banana industry in the Western Hemisphere which exports annually 150 million bunches of this variety, supplying the whole world. To quote Charles Morrow Wilson, "But the fact stands that God alone knows, and during the past 109 years has not revealed, just how the Gros Michel came into being".

Pineapple

The pineapple, a native American plant, was first seen by people from the Old World in 1493 when Columbus and

some of his sailors landed on the Island of Guadaloupe on the second voyage to the New World. At that time the pineapple appears to have been well distributed throughout most of tropical America, except the west coast of South America, and in many places there were evidences of cultivation of this fruit by the Indians. The explorers found several varieties, all of which were seedless or nearly so, whereas wild pineapples growing in the American tropics were extremely seedy. In all probability some selection and improvement had been accomplished by the Indians or their predecessors.

Following its discovery the pineapple was introduced to Europe where for many years it was grown under glass by amateurs. Today these fruits are grown throughout the world in areas suitable to their production out-of-doors. During its long period of cultivation *Ananas comosus* has produced a large number of varieties, yet, strangely enough, only a few of these have survived and have entered into commercial production. In fact, at the present time there are probably fewer popular varieties of pineapples than in any other commercial fruits. Attempts to improve available varieties of pineapples were made by European hothouse gardeners as early as 1765. New seedling varieties were developed by Webber at Miami, Florida, in 1900, and Higgins in 1913 grew a number of seedlings and crosses at the U. S. Experiment Station in Honolulu. The work in Hawaii was resumed in 1915 by H. L. Lyon and R. E. Doty. For some reason none of these seedlings or crosses which were developed between 1765 and 1915 has survived. At the present time J. L. Collins and K. R. Kerns are obtaining interesting and successful results in their breeding program in the Hawaiian Islands, and doubtless improved varieties will eventually be introduced.

Varieties entering into large-scale commercial production throughout the world today are Cayenne, Queen, Red Spanish and Pernambuco. Abachi and Natal are produced in smaller quantities in limited areas. Red Spanish is a white-fleshed pineapple, a little coarse in texture and a little more acid than other commercial varieties. It holds up well during transit and is the variety quite commonly encountered on the fresh fruit markets. It is the principal variety which is shipped to this country from Puerto Rico and Cuba. The Cayenne variety has the largest acreage in cultivation throughout the world, but one rarely sees it on the fresh fruit market in this country. Fruits are large, ranging in weight from four to eight pounds, and the flesh is light yellow and relatively soft in texture. Flavor is excellent. Flesh of the Cayenne is too delicate to stand shipment over great distances, with the result that this variety is very popular for canning. It is used almost exclusively in Hawaii and to a considerable extent in Australia, the Philippines and South Africa. Queen and Natal are small yellow-fleshed varieties with relatively high sugar content. Fruits are smaller than other commercial varieties. Abachi belongs to the Queen group, although it is larger and not quite so high in sugar as Queen or Natal. Pernambuco is a variety popular in northern Brazil where it is used almost entirely for the fresh fruit trade.

With all that is known regarding the discovery of the pineapple and the high quality of commercial varieties as compared to the wild fruits, we have little information concerning the specific origin of the choice varieties available at present. Queen is the oldest named variety, having been mentioned by de Rochefort in 1658. The Cayenne variety was first mentioned in English literature in 1841 and it is believed to have come from French Guiana in 1820. It is pre-

sumed that before this pineapple reached French Guiana, it was cultivated by the Maipure Indians in the upper Orinoco River valley.

This rather fragmentary information more or less sums up knowledge regarding the origin of present-day commercial varieties of pineapples.

Concluding Remarks

Several varieties of fruit mentioned in the preceding account are still in use, particularly the tree fruits—apples, peaches, pears, citrus. One reason for this is that a much longer period is required to bring a fruit tree into bearing than is needed for small fruits and vegetables. A plant breeder may spend years merely culling out undesirable crosses in his program. The hybridization of citrus fruits is fraught with still another difficulty. The seed of an orange or grapefruit may produce more than one seedling, both ovule and nucellus giving rise to a new plant upon germination. The shoot springing from the fertilized ovule is a true hybrid, but that which originates in the nucellus is merely a vegetative sprout possessing only the characteristics of the female parent.

It is not the purpose of this paper to belittle the excellent work of plant breeders in this country who have introduced so many new and desirable types of plants. Our object has been to show how nature's guiding hand supplied us with many of our fruits until plant scientists were able to take over. Research workers in State and Federal agricultural experiment stations and private institutions are performing an excellent service, and many new types of fruit are now in commercial production. According to Darrow, 312 varieties of small fruits were introduced in this country between 1920 and 1950, and 98 of these are of some importance. By 1950 new varieties which were originated by government agencies alone accounted for about 55 percent of the entire strawberry crop, 95 percent of the red raspberries, 50 percent of the purple raspberries, 30 percent of the black raspberries, 5 percent of the blackberries, 95 percent of the blueberries, and 2 percent of the grape crop. Some of the new varieties of peaches are now well established in trade channels and are rapidly becoming favorites among consumers. Other examples might be cited if space permitted.

It should be borne in mind that our present mode of life has placed much greater demands upon the plant breeder than existed fifty years ago. Fruits of good dessert quality and attractive appearance may be satisfactory for home consumption, but they may not tolerate shipment to distant markets or they may not be suitable for canning, dehydrating or freezing. In fact it is now realized that no one variety can be expected to meet all these requirements and that we must look for a type for each specific purpose.

It is surprising, therefore, that so many of the older varieties of fruits have stood the test of time so well. They represent a challenge to modern plant breeders and offer mute evidence of nature's handiwork.

References

Bailey, L. H. Sketch of the evolution of our native fruits. 1898.

———. The standard cyclopedia of horticulture. 1935.

——— and Bailey, Ethel Zoe. Hortus Second. 1947.

Beach, S. A. Apples of New York. 2 Vol. N. Y. Agr. Exp. Sta., Rep. 1903.

Collins, J. L. History, taxonomy and culture of the pineapple. Econ. Bot. 3(4): 335–359. 1949.

Collins, J. L. Notes on the origin, history, and genetic nature of the Cayenne pineapple. Pacific Science V(1): 3–17. 1951.

Crosby, W. J. Origin and development of the pineapple orange. Proc. Fla. State Hort. Soc. 1937: 129–130.

Darrow, G. M. Breeding of small fruits in the United States. Sci. Mon. 75(5): 288. 1952.

Hedrick, U. P. The grapes of New York. N. Y. State Dept. Agr. 15th Ann. Rep. 1908.
———. The plums of New York. N. Y. Agr. Exp. Sta., Rep. **1910**.
———. The cherries of New York. N. Y. Agr. Exp. Sta., Rep. **1914**.
———. The pears of New York. N. Y. State Dept. Agr., Ann. Rep. **1921**.
———. Cyclopedia of hardy fruits. 1922.
———. The small fruits of New York. N. Y. State Agr. Exp. Sta., Rep. **1925**.
Johnson, M. O. The Pineapple. Paradise of the Pacific. 1935.
Miller, E. V., and Schaal, Eva E. Individual variation of the fruits of the pineapple (*Ananas comosus* L. Merr.) in regard to certain constituents of the juice. Food Res. **16**(3): 252–257. 1951.
———. A study of the relation between weight and juice content and composition of pineapple fruits. Food Res. **18**(2): 227–230. 1953.
Robinson, T. R. The bud-sport origin of a new pink-fleshed grapefruit in Florida. Jour. Hered. **12**(5): 195. 1921.
———. The origin of the Temple Orange. Proc. Fla. State Hort. Soc. **1945**: 3–5. 1946.
Smock, R. M., and Neubert, A. M. Apples and apple products. 1950.
Traub, H. P., and Robinson, T. R. Improvement of subtropical fruit crops. U. S. Dept. Agr., Yearbook Sep. 1589. 1937.
Webber, H. J., and Batchelor, L. D. The citrus industry. Vol. 1. History, botany and breeding. 1943.
Wilson, C. M. [Editor]. New crops for the New World. 1945.

Utilization Abstract

Pepper. Commercial pepper is produced from the fruits of the perennial climbing vine *Piper nigrum*, indigenous to Ceylon and South India but today extensively cultivated, for trade of the condiment, in Indonesia, Thailand, Sarawak and India. In an article on the cultivation and marketing of this product, one reads, concerning the two kinds of this spice, that:

" Black pepper is produced simply by drying the clusters of berries. Usually, after picking, the clusters are piled into heaps and left in the sun for several days, when fermentation sets in and the berries turn black. Sometimes the berries are first plunged into boiling water for ten minutes before drying. Boiling results in the skin turning black rapidly and accelerates the drying process. It is also reported to improve the quality of the pepper. After either process the bunches of berries are separated and left to dry thoroughly in the sun. Artificial drying appears to be rather the exception unless weather conditions are extremely unfavourable. When dried, the berries are detached from the spikes by beating with sticks or rubbing off by hand. Finally, the black dried berries are passed through a wide-mesh sieve to free them from impurities and then packed into bags for shipment ".

" White pepper is usually prepared by putting the ripe fruit into bags and placing these in running water for one or two weeks. This treatment softens the skins which are then easily removed by hand or by treading on the berries with the feet. After the skins have been removed, the smooth white kernels are carefully washed and then dried as quickly as possible by spreading them out on mats in the sun. Sometimes artificial dryers are used and in Java small smoke houses, built from palm trees, are used. Very damp wood is burnt in these houses, producing a thick smoke which is led through a pipe and released under the floor on which the berries are spread out to dry. When dried by this method, the finished product often has a heavy smoky odour. Pepper is highly susceptible to mould and rapid drying is therefore essential to produce a first-class commercial product. Should the drying have to be delayed, it is recommended that the decorticated berries be kept under water to prevent discolouration developing. Whether dried by sun or artificial heat the berries must be raked over frequently to prevent mildew developing. When drying is considered complete, the peppercorns may be tested by being bitten. If they split in two they are not sufficiently dry, as when thoroughly dry they crumble easily into several small pieces. The dry peppercorns are then packed into bags ready for marketing ". (E. Brown and Miss D. E. Reader, *Colonial Plant & Animal Products 3*(*3*). *1952–3*).

Rauvolfia serpentina—*Its History, Botany and Medical Use*

This small shrub, native to the Orient from India to Sumatra, has for centuries been used in Indian medicine. In 1952 reserpine, one of several alkaloids in the plant, was isolated from its root and has since been evaluated in western medicine as one of the most valuable drugs for treating high blood pressure.

JOSEPH MONACHINO
The New York Botanical Garden

Recent Applications

Preparations derived from the root of *Rauvolfia serpentina* have recently been admitted in American and European clinical medicine as hypotensive and hypnotic drugs. In addition to lowering blood pressure quite efficiently, apparently without dangerous side-effects, habit formation, withdrawal symptoms or contraindication, these drugs have a sedative or tranquilizing action, said to result from a depressing effect on the hypothalamus. In advanced cases of hypertension they are valuable adjuvants to other agents, notably hydrazinophthalazine or Veratrum. The pure crystalline extract was marketed in November, **1953**, by Ciba Pharmaceutical Products under the commercial name Serpasil (Ciba). The crude drug is also in the American market, for instance, as Raudixin (Squibb) which contains the whole powdered root of *R. serpentina*. Raudixin tablets were placed on the market in May, **1953**. Rauwiloid (Riker) is a purified extract containing a mixture of principles. Serpina, manufactured by the Himalaya Drug Company in Bombay, has been sold in India for a comparatively long time. Experiments with the preparation were described by Bhatia and by Kapur in **1942**. The active principle of Serpasil is a tranquilizer-antihypertensive alkaloid bearing the chemical name " reserpine ".

Early History

R. serpentina has an ancient history. It is said to appear in Sanskrit as an Ayurvedic medicine named Sarpagandha and Chandrá. Chandrá means moon and refers to the use of the plant in the " moon's disease " or lunacy; Sarpagandha, snake's smell or repellent, refers to the use as an antidote for snake-bite. Rheede in **1686** probably mentioned this species, at least in part, under the name Tsjovanna (or Sjouanna) Amel-Podi; he noted the use of the root against snake-bite and the sting of scorpions. Kaempfer in **1712** described the plant and its curative properties under the name Radix Mungo. Burman in **1737** applied the term Lignum Colubrinum to it. Linnaeus in Materia Medica, **1749**, used the pharmacopoeic appellation Serpentini Lignum. Rumphius named the plant Radix Mustelae, in reference to the legend that the mongoose has recourse to it when bitten by a poisonous snake; he stated that the species came to his notice in **1693**. Various other curative properties were early attributed to the plant, and it has accordingly been regarded as

a febrifuge, tonic, stomachic, sedative, soporific, eclampsia relief, cough-sedative, diuretic, purgative and anthelmintic. Trimen noted its use against hydrophobia. Dymock (1879) stated that in Bombay most of the laborers who came from southern Koncan kept a small supply of the root which they valued as a remedy in dysentery and other painful affections of the intestines. Roxburgh reported that it was administered to promote delivery in child-birth; Wight added that it was supposed to act on the uterine system somewhat in the manner of Ergot; Khory stated the root was said to cause abortion if given to pregnant women. Rama Rao described the " whole plant dried in shade, powdered and given in honey as a remedy in rheumatism, all poisons, insanity, epilepsy, fits and eczema ". " The juice of the fresh leaves has been mentioned for the treatment of corneal opacities " (Kapur). Dalzell and Gibson reported the plant used " to poison tigers ". It will be noticed that many of the empirical uses have a common denominator, the proven sedative or relaxing efficacy of the drug; reports of other presumed properties may have stemmed from a mistaken identity of the plant.

Modern Use in India

Before its introduction into occidental medicine, the dried root had already been on the market in India for about 20 years. One manufacturing firm alone claimed to have sold over 50 million tablets of the dried root. Sen and Bose in 1931 reported the drug valuable and safe in the treatment of high blood-pressure, " almost to a precision not found possible with any other drug, Eastern or Western ". They found it effective in insanity with violent maniacal symptoms. Deb in 1943 stated that *R. serpentina* checked psychotic excitability more effectively than any of the barbiturate group of drugs. The Indian Pharmacopoeial List in 1946 described the products Extractum Rauwolfiae Liquidum, Extractum Rauwolfiae Siccum and Tinctura Rauwolfiae. In 1949 Vakil concluded that after extensive trials of various hypotensive remedies in several thousand cases of hypertension, in both private and hospital practice during the previous ten years, he found *R. serpentina* to be the most consistently successful drug, meriting a definite place in medicine; it lowered both systolic and diastolic blood-pressure, and it was non-toxic, with only mild side-effects. In reply to a questionnaire that Vakil issued to 50 physicians all over India, 46 voted for *R. serpentina* as the best hypotensive agent in their experience.

Botany

R. serpentina is a member of the Apocynaceae, a family notable for its many biologically active principles. The species is widely distributed in tropical India, Ceylon and Java.

Synonymy. *Rauvolfia serpentina* (L.) Benth. ex Kurz, For. Fl. Br. Burm. 2: 171. 1877. (Spelled " *Rauwolfia serpentinum* ".)

? " *Clematitis indica foliis perficae, fructu periclymeni* " Bauhin, Pinax 301. 1671.

" *Tsjovanna-Amel-Podi* " & " *Sjouanna-Amelpodi* " Rheed., Hort. Malab. 6: 81. t. 47. 1686.—pro parte?

" *Radix Mungo* " Kaempf., Amoenit. Exot., fasc. 3: 573. 1712.

" *Ligustrum foliis ad singula intermedia ternis* " Burm., Thes. Zeyl. 141. t. 64. 1737.

" *Ophioxylon foliis quaternis* " L., Fl. Zeyl., ed. 1, 188. 1747. (Description erroneous; corrected under Restituenda, p. 239.)

Ophioxylon serpentinum L., Sp. Pl. 1043. 1753.

" *Radix Mustelae* ", " *Raiz de Mongo Alba* ", & " *Raiz de Mongo Rubra* "

FIG. 1. *R. serpentina,* collected by Boorsma in Krawang, Java, in or shortly before 1907. Flowering and fruiting plants, including roots. The stems are 22 and 23 cm. long; the flowers are not fully expanded. (*Photo by courtesy of The New York Botanical Garden*).

Rumph., Herb. Amb. 6 Auctuarium (7): 29, 30. t. 14. 1755.

Ophioxylum trifoliatum Gaertn., Fruct. 2: 129. t. 109. 1791.

Ophioxylum album Gaertn., Fruct. 2: 129. 1791.

Ophioxylon Salutiferum Salisb., Prod. Stirp. 146. 1796.—superfluous name.

Tabernaemontana cylindrica Wall., Cat. 4451. 1830.—nom. nud. (Fide J. D. Hook., Fl. Brit. Ind.)

? *Ophioxylon Belgaumense* Wight, Ic. Pl. Orient. 4(2): 2. 1848.

Ophioxylon obversum Miguel, Fl. Ind. Bot. 2: 405. 1856.

Rauwolfia trifoliata (Gaertn.) Baill., Hist. Pl. 10: 171. 1891.

Rauwolfia obversa (Miquel) Baill., Hist. Pl. 10: 171. 1891.—Non Koord., 1901, as to description.

Description. Erect evergreen subshrub, 0.2–0.6 (–1) m. tall, glabrous, lactescent. Root bitter, its main axis vertical, single (rarely branched), tapering to base, up to 20 (–40) cm. long, 1–2 cm. thick, rimose, greyish rusty to brown. Rhizome resembling the root (fide Wallis and Rohatgi). Stem usually unbranched, slender; bark pale. Leaves usually more crowded towards upper part of stem, mostly 3-whorled, or a few leaves occasionally opposite or even alternate (leaves described as varying from opposite to 3–5-whorled); petiole 5–15 (–20) mm. long, glandular at axil; blade membraneous, green above, pale beneath, oblanceolate or obovate, sometimes lanceolate, 7–16 cm. long, 3–9 cm. broad, acuminate and finely acute, varying to blunt or evenly rounded at apex, tapering at base, the lateral nerves arcuate-ascending; 7–15 pairs, widely spaced, the principal ones mostly 1–1.5 cm. apart near middle of blade; fainter veins present between the principal lateral nerves. Inflorescence terminal or sometimes axillary, usually in dense crowded many-flowered cymes, forming a hemispheric head at the end of the peduncle; axis 0.5–1.5 cm. long; peduncle usually long and unbranched, sometimes sparsely branched, 5–9 (–13) cm. long; bracts minute, subulate from a triangular base; pedicels very short. Calyx-lobes esquamulose, almost free, deltoid to lanceolate, 1.3–3 mm. long, acute at apex, often with 1 or 2 minute teeth on margin near base. Corolla pink or white, salverform; tube 11–16 mm. long, slightly swollen at location of anthers slightly above middle, glabrous outside, pilose inside from about middle to orifice, lobes ovate-orbicular, rounded at apex, 1.5–3.5 mm. long, glabrous, convolute in bud with left margin overlapping. Stamens free, inserted well below orifice of tube, 3–5 mm. from apex; filaments very short; anthers oblong, 1.3–1.4 mm. long, apical mucro short if present, thecae rounded at base, dehiscent their full length. Disk subtending and partly cloaking the ovary, cylindric, 0.6–0.8 mm. long, truncate or lightly undulate at margin. Ovary about 1.2 mm. long, truncate, rounded or slightly concave at apex, narrowed to a stipe-like base, glabrous; carpels united at base to about length of disk; ovules suspended, two in each cell. Style about 8 mm. long; clavuncle short-cylindric, about 1 mm. long, membraneous tunicate at base, fringe-indusiate at apex; stigma of 2 minute apiculi. Drupes double (sometimes single by abortion), united about half way, oval, slightly flattened, 5–6.5 mm. long, 4.5–5 mm. broad; apices blunt, divergent so that the sinus makes an open V; flesh thin; endocarp osseous, lightly rugose; disk remaining as a thin collar at base of fruit. Seed single in each carpel, oval, flattened, about 6 mm. long; endocarp copious, soft; embryo erect; cotyledons aplanate, broadly oval, about 2 mm. long, 1.8 mm. broad; radicle cylindric, about 2 mm. long. An herbarium specimen (Herb. Hort. Bog. 6597, Rembang, Java) of a plant with abnormal corollas was examined: some of the corolla-lobes narrowly spatulate-lanceo-

late, longer than corolla-tube, up to 7 mm. long, pilose inside near base; anthers more or less abortive; ovary tapering at apex; disk low.

Type of the Species. Hermann's Ceylon collection deposited in the British Museum. Hermann collected mostly in the neighborhood of Colombo. Henry Trimen studied the Hermann collection and verified the type (Jour. Linn. Soc. **24**: 153. 1887). In Species Plantarum, Linnaeus cited Burman and Bauhin, besides his earlier Flora Zeylanica.

Distribution (mostly from literature). India, Ceylon, Andaman Islands, Burma, Siam, Java, Sumatra. Sub-Himalayan Pakistan and the Indian Union throughout where the habitat permits, in a variety of soils, in grassy, usually damp or shady places, ascending to over 1200 meters in the Khasia Mts.; the upper Gangetic Plains, Dehra Dun, Siwalik Range and in the Sub-Himalayan tracts of Rohilkhand, N. Oudh and Gorakhpur District westward to Sirhind along the base of the Punjab Himalaya, and eastward to Sikkim, Assam and N. and C. Bengal, and from Bombay through C. and S. India to Travancore; common in the Terai and Lower Hills up to 600 meters in Northern Bengal, common in the Koncans, Bombay Presidency; W. Ghats in Madras, all districts, moist forest undergrowth from low level up to about 1000 m. Throughout Ceylon, common in shady places in grass in moist regions up to 600 meters, banks of rivers, paddy fields. Burma, " very frequent in the mixed and open, especially in the savannah forests, all over Pegu and Martaban down to Tenasserim " (Kurz). Siam, " Pahombuk, Muang Fang, 1000 m. et Doi Intanon, 1700 m. (ex Hosseus) " (Craib). Java,[1] scattered throughout to an altitude of 650 meters or higher; residencies Batavia, Besoeki, Cheribon, Djapara, Kediri, Madioen, Pekalongan, Pasoeroean, Preanger, Rembang, Semarang. Amboina, where introduced from Java, according to Rumphius' observation in 1693; not represented in the Amboina collection (Merrill). Sumatra, fide Kaempfer. Wight stated that the plant is one of great beauty and much cultivated as an ornament.

[1] The notes presented by Koorders (Exkursionsflora von Java 3: 74. 1912) refer to *R. perakensis* (or *R. verticillata*) and *R. serpentina* together, for Koorders, like some other botanists, did not distinguish the two species.

Vernacular Names. India: Chandrá (Bengali), Ch'hota-chand (Hindi), Chivan-amelpodi or Covannamiloori (Tamil), Dhannerna or Dhan-barua (Oriya), Pálalganni or Pátala-gandi (Telegu). Ceylon: Acawerya. Java: Akar Tikoes, Poelé (or Poeleh) Pandak.

The following is an alphabetical list of all the vernacular names encountered for the species:

Acawerya
Aika-wairey
Akar-tikoes (Accarticos)
Bongmaiza
Bhudra
Chandrá
Chandrika
Chota-Chand
Chota-Chard
Chundrika
Chundrushoora
Churmuhuntree
Chivan-amelpodi
Chuvanna-avilpori
Covannamiloori
Dhannerna
Dhan-barua
Eiya-kunda
Ekawerya
Garudpathal
Hadki
Harkai
Harkaya
Ichneumon plant
Karai
Karavi
Karuvee
Kshermakshi
Makeshwar Chakrika
Makeshwar Churna
Matavi-aloos
Moogsavel
Nogliever
Nundunee
Pagal-ka-dawa
Pálalganni
Pátala-agandhi
Pátala-gandi
Pátala Garuda
Pátalgarur
Poeheh Pandak
Poelé Pandak (Pule Pandac)
Pushoomehunukarika
Radix Mungo
Radix Mustelae
Raiz de Mongo Alba
Raiz de Mongo Rubra
Rametul
Ratekaweriya
Ratu Eka-weirya
Sapasan
Sarpagandha
Sjouanna-Amelpodi
Sung
Suvapaval-poriya
Tsjovanna Amelpodi
Talona
Vasoopooshpa
Vasura

" Makeshwar Chakrika " and " M. Churna " were the names used by Maka-

mahopadhyaya Gananath Sen for the pill or tablet preparation and the powdered drug. " Pagal-ka-dawa " was the name of the drug used as an insanity specific in India. Some of the names listed above may be due to mistaken identity. Also, as is often the case, the same vernacular name may be applied to other species. For example, " Poelé Pandak " has been applied to *Plumbago indica* L. and to other species, according to Heyne. Sen and Bose pointed out that " Sarpagandha " has been employed in Ayurvedic literature to mean " Rasna ", which cannot be identified with *R. serpentina;* " Chandrá " and " Chandrika " have been applied to five or six drugs, none of them identified as *R. serpentina.*

Field Observations and Culture[2]. The flowers are reported red or white, or whitish tinted with shades of red. The Jacquin illustration shows red corolla-tube and white limb. Drupes purplish-black when ripe (" lateritio-rubra " Gaertner; " glossy crimson " Kurz). Nucleus white, oily, vapid subsweet (Kaempfer). Pedicels and calyces bright red (calyx green, somewhat red at the tips of the lobes, according to Wendland). Cooke quotes W. Jones: " Few shrubs are more elegant, especially when the vivid carmine of the perianth is contrasted not only with the milk white corolla, but with the rich green berries which at the same time embellish the fascicle; the mature berries are black and their pulp light-purple ". The plant flowers from April to July (Nov., Dec., fide Duthie) and fruits from July to September, but flowers and fruits occasionally may be found throughout the year.

In cultivation under glass the plant does not seem to bear fruits. Jacquin stated that he examined flowers several years and found that they were early deciduous, and that no fruits were formed. Wendland observed the plant blooming for six years, but not setting fruit. Sims noted that the cultivated plant requires heat but does not like the sun.

A plant raised from seed obtained from Calcutta in 1901 was in the Conservatory of The New York Botanical Garden, and a flowering specimen was collected in March, 1906. At the present time there is no living plant of *R. serpentina* either at New York or at the U. S. Department of Agriculture, Beltsville, Maryland. E. A. Menninger maintained in Florida a nursery stock of the species as an ornamental plant, but his entire stock was sold almost overnight last year when there began to be great interest in the drug.

J. Douglas, Curator, Botanical Garden of Indonesia, is intimately acquainted with the plant in the field. He communicates that the plant in Java reaches maturity and maximum height (about 50 cm.) in about two years, and that afterwards the root increases in size. The plant fruits readily after flowering. Experiments conducted in West Java demonstrate that stem-cuttings root, although not easily. Propagation by seed was difficult; 30 percent germination was obtained. The plant did not thrive well in the very moist climate of West Java (rainfall about 4000 mm. a year).

D. M. A. Jayaweera, Superintendent, Royal Botanic Gardens, Peradeniya, Ceylon, reports that *R. serpentina* is common in Ceylon, and that the quickest way of propagating it is by division of the root-stock. One hundred percent of divided root-stocks established in two weeks; the same percentage of terminal cuttings sprouted roots in four weeks in sandy beds. Seeds took two or three months to germinate, as they are protected by a thick coat. Boiling or burning may encourage early germination.

[2] Roxburgh stated that the plant in rich soil is a large climbing or twining shrub; in poor soil, small and erect. The error " large climbing or twining shrub ", has been repeated by Wallis and Rohatgi, Watt, etc., even as late as 1952 (by Trease).

The Root. Dymock stated that the odor of the fresh root is acrid, and that the wood is remarkably starchy. He presented a short description of the root and its anatomy. Wallis and Rohatgi wrote that the rhizomes closely resemble the roots but are less uniform in diameter; they differ histologically in certain respects only, best distinguished by the very small diameter of the central pith in the rhizome exhibited in transverse sections. They found no typical laticiferous tubes in the roots and rhizomes. Youngken stated that the resin cells may occur in the cortex, phloem and xylem, and are especially abundant in the Dehra Dun variety. He described the microscopic structure of the root of commerce, huge amounts of which, he noted, have been imported by manufacturing pharmaceutical firms in the United States.

According to Dymock (1879), the root formerly was not an article of commerce. The Indian Pharmacopoeial List of 1946 specified that the root of *Rauvolfia* be collected from three- to four-year plants in autumn, and that the material contain not more than two percent of organic admixture and not less than 0.8 percent of total alkaloids. Chakravarty et al. found that the dried root contains about one percent of total alkaloids; Gupta and Kahali detected 1.21–1.36 percent.

Illustrations. Excellent colored illustrations of the flowering plant are presented by Jacquin, Sims and Trattinick; others by Wendland (flower analysis in color), Wight (stem with leaves, flowers and fruits; flower and fruit analyses, embryo), Gaertner (fruit analysis), Burman (stem with leaves and fruits), Lamarck (stem with leaves, flowers and fruits; fruit analysis), Rumphius and Rheede (rough sketches; stem with leaves, flowers and fruits; root). A colored illustration of undesignated origin (stem with leaves, flowers and fruits) is being distributed by S. W. Akkarappatty and Co., Wholesale Drugs and Herbs Dealers, Trichur, S. India. A photo is shown by Youngken (stem with leaves and inflorescence; cross-segment of root). Wallis and Rohatgi offer extensive anatomical drawings of the root and rhizome; their reproduction of the flowering plant is taken from Wight. Pool presents a microscopic view of the epidermis and other anatomical features, also the root and a rough sketch of the stem with leaves, flowers and fruits. Index Londinensis also lists the following (not seen): Basu (Ind. Med. Pl., t. 602. 1918), Greshoff (Nutt. Pl., t. 46. 1900), Plenck (Ic. Pl. Med., 8 t. 732. 1812). Miquel observed that the illustrations in Burman and Wight are not of the species, the former probably being referable to *Ophioxylon ceylanicum* Wight. On the contrary, both drawings show connate drupes and a crowded inflorescence, and are in general fairly representative of *R. serpentina.* The drawing of *Ophioxylon ceylanicum* shows separate drupes and a relatively loose inflorescence; it is good for *R. densiflora.*

Discussion of Synonymy. The original spelling of the generic name by Linnaeus in Genera Plantarum in 1737 and subsequently to the seventh edition in 1767 was *Rauvolfia.* This orthographic variation was also used in the first edition of his Species Plantarum and subsequently to the seventh edition. In the eighth edition, 1778, the spelling was changed to *Rauwolfia,* which is the commonly accepted form. In strict usage and in compliance with the International Code of Botanical Nomenclature, the name should be spelled *Rauvolfia.*

In the foregoing synonymy under *R. serpentina,* there cannot be any assurance regarding identity of the plant referred to by Bauhin. The same doubt holds for other early works. Rheede's description of connate drupes, corolla extended near the middle, and bitter roots identifies his species with some greater confidence. His illustration,

however, depicted opposite, not ternate, leaves, and he described the size of the plant to reach the height of a man, which is much too tall for *R. serpentina*. On the other hand, Kaempfer's description can hardly be questioned: size of the plant about one foot, the drupes coalesced at the base and about the size of coriander fruits, the flowers globular-congested, the simple bitter root about a span long and the thickness of a finger. Burman's illustration adequately characterizes the species.

Rumphius noted two color forms of Radix Mustelae. He observed that they did not differ in leaf, flower or fruit, except that Radiz de Mongo Rubra had firmer leaves, reddish beneath, mostly ternate, reddish flowers, and roots not so bitter. He aptly compared the fruit to the likeness of two pepper grains pressed against each other. The corolla was depicted inflated near the middle, and the fruits apically rounded as in *R. serpentina* instead of pointed as in *R. verticillata*. Burman, in Flora Indica (pp. **42** & **218**. **1768**), placed Radix Mustelae of Rumphius in the synonymy of both *Ophiorrhiza Mungos* L. and *Ophioxylon serpentinum*. Rumphius' characterization of the seed and his assertion that the plant is lactescent precludes *Ophiorrhiza* (Rubiaceae).

Linnaeus' description under n. **398** in Flora Zeylanica is altogether incorrect for the species (corolla-limb with a cylindric nectarium as in *Narcissus*, calyx bifid, stamens two). The error was rectified under his Restituenda in the same work. Linnaeus cited the Acawerya of Hermann's catalogue, besides previous literature, Burman, Bauhin, and " Garc. Arom. 163 ".

Gaertner illustrated connate drupes for his *Ophioxylum trifoliatum*. The species is thus best referred to *R. serpentina*. *Ophioxylum album* was based on Rumphius' illustration of Raiz de Mongo Alba. It is sometimes united with *Ophioxylon majus* Hasskarl. The latter is most probably the Java representative of *R. verticillata* (*R. perakensis*), a shrub usually over four feet tall and with free drupes. Rumphius stated that Raiz de Mongo Alba did not exceed two feet in height. The sketch showed opposite, not whorled, leaves, and this was noted by Gaertner as a point of difference from his *O. trifoliatum*. The sketch was very rough, and the leaf arrangement is best regarded as inaccurate.

Hooker wrote about *Ophioxylon Belgaumense*: " I find no specimen of this in Wight's Herbarium; but for the calyx it seems identical with *R. serpentina* ".

The type of *Ophioxylon obversum* Miquel, an Horsfield flowering specimen from Blambangan, Java, compares very well with *R. serpentina*. Miquel incorrectly described the cymes and calyces of *R. serpentina* as pubescent, indicating that he did not clearly understand the species. Koorders, unaware that Baillon had already effected the combination, published *Rauwolfia obversa* (Nat. Tidsschr. Ned. Ind. **60**: **243**. **1901**). His basonym was Miquel's name, but his description was of *R. verticillata*. He observed that the long fruit of his Tenger collection made separation of the species from *R. serpentina* recommendable. He annotated the Tenger collection **38156**β: " = R. obversum Miq. = Horsf. Apocy. n. 22! in herb. Kew ". Later, in **1912**, Koorders altered his concept and referred both the Tenger species and Miquel's *Ophioxylon obversum* to *R. serpentina*, " sensu latissimo ", noting the latter to be a very polymorphic species. Thus by falling into a double error he arrived at the correct conclusion regarding the synonymy of *R. obversa*.

Hunteria sundana Miquel is placed in the synonymy of *R. serpentina* by Heyne. Miquel, himself, indicated the species to possess the character of *Ophioxylon*. However, the original placement of it in *Hunteria*, a genus with free

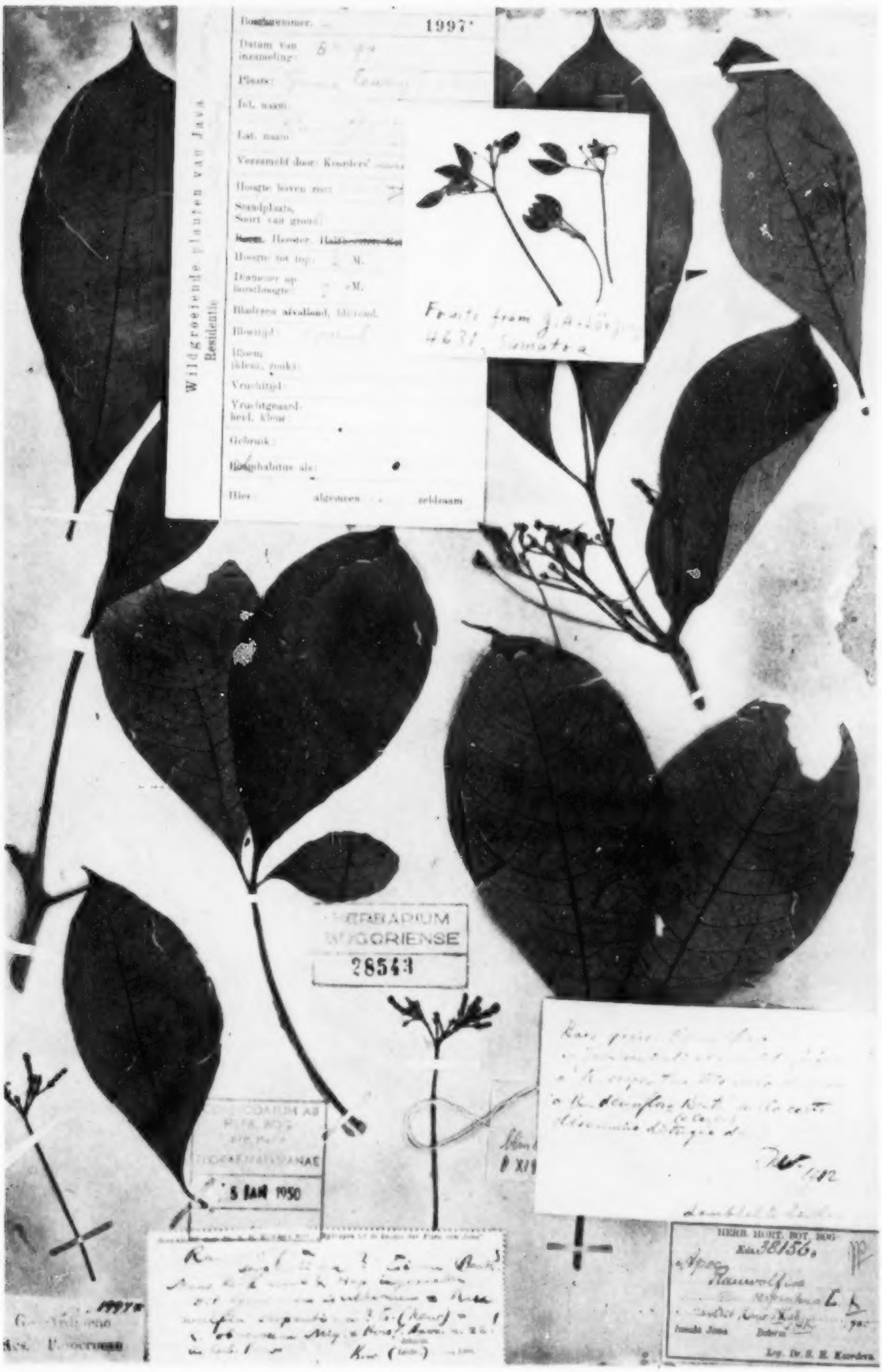

FIG. 2. *R. perakensis* (a variety or form of *R. verticillata*), collected by Koorders (38156B) on Mt. Ardjoeno, Pasoeroean, Java, 8 Nov. 1899. This species has been mistaken for *R. serpentina*, but the loose habit of its inflorescence distinguishes it. The fruits are from a specimen collected by Lörzing in Sumatra. They are free and pointed, whereas those of *R. serpentina* are half united and blunt. (*Photo by courtesy of The New York Botanical Garden*).

fruits, and the description of the fruits as ellipsoid subsessile would suggest a species other than *R. serpentina*. Heyne did not distinguish *R. serpentina* from *R. verticillata*.

Species Related to *R. serpentina*. *Rauvolfia* is a large genus, comprising about 110 species according to Pichon. This number probably will be greatly reduced when the synonymy is known. It is distributed in the tropics of nearly the whole world: Middle and South America, Africa, India, Malaya, China and Japan. The genus apparently is absent from Australia and New Zealand. The most numerous species are in America and Africa. The species vary in size from dwarfs with annual shoots up to 15 cm. high (*R. nana* E. A. Bruce) to rather large trees about 25 meters tall and 30 cm. in diameter (*R. caffra* Sond.).

Pichon recognizes 14 sections in the genus. In section *Ophioxylon* (characterized by the more or less coalescent drupes), where he placed *R. serpentina*, he has (as doubtful) one other species only, *R. membranifolia* Kerr, of which he studied the fruits. The drupes of *R. micrantha* Hook. f. are connate to the middle, as described by Hooker. The sinus at the apex of the double-fruit of *R. micrantha* forms a much more open angle than that in *R. serpentina*, so presenting a broadly emarginate to truncate apex.

The drupes of *R. densiflora* (Wall.) Benth. ex Hook. f. are free, larger and more pointed at the apex than those of *R. serpentina*. The inflorescence is looser, notwithstanding the specific appellation " densiflora ". The stamens are located at the summit of the tube, the corolla-lobes are longer. *R. verticillata* has the fruit and inflorescence character of *R. densiflora*. Its stamens, however, like those of *R. serpentina*, are situated decidedly below the orifice of the corolla-tube.

R. perakensis King and Gamble, which has been called Poeleh-padak in Java and confused with *R. serpentina*, is infraspecifically, if at all, distinct from the Chinese *R. verticillata* (Lour.) Baill. (= *R. chinensis* (Hance) Hemsl.). It has also erroneously been called *R. densiflora* in Java. *R. majus* (Hassk.) Nichols. may also be the same as *R. verticillata*.

Under his section Dissolena, Pichon indicated that he studied *R. verticillata*, *R. chinensis*, *R. perakensis* and *R. majus*. He listed these species separately, as though distinct; but the first two are synonymous, and the remaining two are only varietally, if at all, distinct from *R. verticillata*.

A study of the relatives of *R. serpentina* would require examination of the following additional species: *R. peguana* Hook. f. (= probably a form of *R. verticillata*), *R. microcarpa* Hook. f., *R. Beddomei* Hook. f., *R. membranifolia* Kerr, and *R. ophiorrhizoides* (Kurz) Kerr (= probably a form of *R. verticillata*). Not a single specimen of these seven species is available in the principal American herbaria (a specimen named *R. ophiorrhizoides* is at the Arnold Arboretum, but its determination is doubtful). The specimens of *R. Loheri* Merrill and *R. membranacea* Merrill are poor; *R. rivularis* Merrill is represented by a single flowering specimen. Stapf described *R. serpentina* var. *gracilis* from Borneo, but this variety is better referred to *R. verticillata*. For a complete survey two other names should also be investigated, *Ophioxylon Belgaumense* Wight and *Hunteria sundana* Miguel.

Chemistry and Pharmacology

Other Rauvolfia Species. Eight or nine species of *Rouvolfia* have been investigated chemically. *R. canescens* L. and *R. heterophylla* Roem. and Schult. (southern Mexico and the West Indies to northern South America) are considered by Woodson as varieties of a single

species, *R. hirsuta* Jacq. and *R. hirsuta* var. *glabra* (Muell. Arg.) Woods. Chemical literature on five African species has been seen: *R. caffra* Sond. (Belgian Congo, Transvaal), *R. mombasiana* Stapf (East Africa, Kenya to Mozabique), *R. natalensis* Sond. (Nyasaland, Natal), *R. vomitoria* Afzel (West Africa, Belgian Congo, Tanganyika), and *R. obscura* (Belgian Congo).

Adulterants. Youngken states that the roots of *R. perakensis*, *R. densiflora*, and especially of *R. canescens* have been found as substitutes and adulterants in commercial lots labeled " Rauwolfia Serpentina Root ". Mookerjee also revealed that the roots of *R. canescens* are sometimes used to adulterate those of *R. serpentina*. *R. canescens* is American but sometimes occurs in areas of India where *R. serpentina* abounds. The species is not generally treated in the floras of India. Haines (1922) states: " Orissa, near Cuttack, etc., apparently an escape from cultivation! "; Gamble (1923): " found in gardens and sometimes run wild in the neighborhood of Madras ". However, Mookerjee (1941) wrote that the species is locally known as " Barachándá " and that it inhabits the moist and hot regions of India.

Chemistry of *R. serpentina*. The chemical, pharmacological and clinical literature on *R. serpentina* or its alkaloids is extensive, and only partial mention of it can be made here. Reserpine was isolated for the first time by Müller, Schlittler and Bein in 1952. The chemistry of this alkaloid was thoroughly studied in 1953 by Dorfman, Huebner, MacPhillamy, Schlittler and André (Research Laboratories of Ciba Pharmaceutical Products, Inc., Summit, New Jersey); Furlenmeier, Lucas, MacPhillamy, Müller and Schlittler; Klohs, Draper, Keller and Petracek (Riker Laboratories, Inc., Los Angeles, Calif.); Neuss, Boaz and Forbes (Lilly Research Laboratories, Indianapolis, Ind.); Stoll and Hofmann. Chatterjee and Bose announced the new alkaloid rauwolfinine in 1951; Rose further studied this compound in 1952. Stoll and Hofmann isolated the new alkaloid sarpagine in 1953. Bodendorf et al. conducted pharmacological tests with the alkaloid raupine in 1953. The alkaloid serpentine was investigated by Schlittler and Schwarz in 1950.

Wilkins and Judson (1953) confirmed the distinct pharmaceutical excellency of *Rauvolfia;* they found that the drug given in conjunction with other hypotensives " appeared to exert a remarkable additive, if not synergistic, hypotensive effect ". The side effects were few and none serious, they concluded, those worthy of emphasis being bradycardia, nasal congestion, sedation and a tendency to gain weight. In a paper summarizing the drugs used orally in the current treatment of hypertension, Wilkins (Nov. 1953) concluded that *Rauvolfia* is " particularly useful alone for relieving young, labile, psychoneurotic hypertensive patients with tachycardia ". Other physiological or pharmacological studies have been conducted by Chakravarty and Chaudhuri (1951), Roy (1950), Mazumdar and Mukherji (1950), Bhatia (1942), Kapur (1942), Paranjpe (1942), Raymond-Hamet (1936–1949), and also Chopra, Gupta, Dutt, van Itallie and collaborators.

Siddiqui found chemical differences in the roots of *R. serpentina* collected in the hot swampy districts of Bihar and in the climatically milder Dehra Dun Valley; Bhatia and Kapur detected pharmacological differences in the roots from the two localities. In a preliminary investigation of two known and four unknown varieties from several sources, Nelson and Schlagel found the Dehra Dun variety showing the greatest activity. A method of assay of the roots was elaborated by Mahadeva Lal Schroff and Rattan Lal Bhatia. A micromethod for

determination of the alkaloids was presented by Bakshi.

In 1888 Wefers Bettink investigated the chemistry and pharmacology of the roots of Poeleh Padak obtained from a druggist in Cheribon. He identified the plant as *R. serpentina*, but did not see the flowers to check the identification. The taste of the root he studied was sharp, like that of horse-radish, not bitter as described by Rumphius or as in the Dymock root. Extracts killed earthworms quickly. He called the principle " ophioxyline ".

The Merck Index (6th Ed., 1952) states that ophioxyline is obtained from the roots of *R. serpentina;* it lists Wefers Bettink and two other old references, Greshoff (1890) and Warden and Bose (1892). As previously indicated, Poeleh Padak in Java has been applied to other species besides *R. serpentina*. It is doubtful that Wefers Bettink correctly identified the material he studied. Neither of the two remaining citations given in the Merck Index supports the presence of ophioxyline in *R. serpentina*. Greshoff indicated the identity of ophioxyline with plumbagine and suggested that *R. serpentina* had been confused with *Plumbago rosea* L. Both species, he pointed out, bear the same name, " Poeleh Pandak ", in Java. Warden and Bose did not mention ophioxyline but merely announced the extraction of an alkaloid which they provisionally termed " pseudobrucine ".

Additional alkaloids reported for the species are: ajmaline, ajmalinine, ajmalicine, isoajmaline, isorauwolfine (possibly identical with isoajmaline), neoajmaline, rauwolfine (possibly identical with ajmaline), rauwolscine[3] serpentinine. Wehmer also lists serposterine.

[3] Rauwolscine was listed for *R. serpentina* by Mazumdar and Mukherji in 1950. This alkaloid was first isolated from *R. canescens* by Mookerjee in 1941.

The Squibb Institute for Medical Research has issued a typewritten four-page list of 46 references dealing with the chemistry and pharmacology of *R. serpentina*, embracing the years 1931 to 1953. Two pages of additional references, containing 18 entries, were included in December, 1953. A conference on " Reserpine (Serpasil) and other alkaloids of Rauwolfia serpentina: chemistry, pharmacology and clinical applications ", sponsored by The New York Academy of Sciences, was held in New York City on February 5, 1954. An annal with this title, comprising about 200 pages, is to be published by the Academy in 1954.

The Drug in Commerce. Serpasil is not yet commercially available in Great Britain, according to a private communication (Dec. 1953) from W. Gwynne Thomas, Pharmacy Department of the University of Manchester. Mr. Thomas wrote further that " Messrs. Ciba Laboratories Ltd. have a small stock of experimental material at their laboratories in Horshan, Sussex, which is available to persons wishing to investigate the properties of the substance, or to members of the medical profession who wish to conduct clinical trials ". Products of *R. serpentina* have been marketed in Switzerland, Germany, and in this country.

A brochure prepared by Squibb summarizes the advantages of Raudixin. Some of the advantages given are: safety, mild brachycardia, sedation and laxation, symptomatic improvement, convenient oral dosage. Another example of commercial advertisement of the drug appears on the back covers of the 1953 June, July and August issues of the American Journal of Pharmacy, where Raudixin Tablets (Squibb) are stated to permit an improved approach to ideal hypotensive therapy. It is asserted that the drug has a more stable hypotensive effect than other agents; critical adjust-

ment of dosage is unnecessary; and tolerance to the hypotensive effect has not been reported. In the September issue Squibb advertised that wide clinical experience to date still makes the whole crude root the preferred form of the drug. A brochure circulated by Ciba states that Serpasil, being a single pure crystalline alkaloid, yields predictable constant results and offers unvarying potency with accuracy in dosage in comparison with whole root therapy. Mazumdar and Mukherji (1950) pointed out that ajmaline and serpentinine raise the blood pressure; hence the total alkaloids of the root contain components which act antagonistically, raising as well as lowering the blood pressure.

Treatment in Standard Literature. As indicated in the 24th edition, 1947, of the Dispensatory of the United States, the drug is not yet official in the U. S. Pharmacopoeia, the Pharmacopoeia of Great Britain or the National Formulary. C. O. Lee's, The Official Preparations of Pharmacy (2nd Ed., 1953), does not contain *Rauvolfia*, nor does M. E. Howard's Modern Drug Encyclopedia and Therapeutic Index (5th Ed., 1952). The species has not yet been generally admitted in textbooks on pharmacognosy. It probably will be a standard item in the pharmacopoeias and pharmacognosy textbooks of the future.

The species is mentioned briefly in the 6th ed. (1952) of Trease's " A Text-book of Pharmacognosy ", but only in connection with the " Rauwolfia drug " long used in Indian medicine. Trease states that the alkaloids in *R. serpentina* do not appear to account for the sedative and hypnotic actions. He relied on Gupta et al. (1944, 1947) and possibly on Dutt et al. (1947) who claimed that the principle possessing these properties resides in the oleoresins; but Müller et al. in 1952 isolated the sedative alkaloid reserpine from the oleoresin fraction.

Summary

Rauvolfia serpentina, an ancient Indian medicine, is now ranked amongst the most valuable drugs for the treatment of high blood-pressure. It is particularly useful in mild hypertension or as an adjuvant in advanced cases. Until quite recently, it was neglected by the Western World, notwithstanding that careful investigation of the crude drug in India had consistently rendered a very high account of the plant. In 1952 the pure crystalline antihypertensive-tranquilizer alkaloid reserpine was isolated from the root.

R. serpentina has an Indo-Malaysian distribution. It is a subshrub with a congested inflorescence and half-connate drupes. Its botany is rather simple. There are only a few related plants likely to be confused with the species when adequate botanical material is examined. Sterile specimens may cause difficulty. It can hardly be entirely explained why *R. perakensis*, itself merely a variety or form of the Chinese *R. verticillata*, has been indiscriminately identified with *R. serpentina* in Java. The fruit character easily distinguishes the two.

Trial cultivation of *R. serpentina* is being made. Propagation by root-stock cuttings is successful. As there are strains of the species that differ in activity, particularly good strains should be sought for large-scale plantations.

The genus *Rauvolfia* is large and has a wide distribution in the tropics. Only a small percentage has been carefully investigated chemically and pharmaceutically. Numerous laboratory and clinical studies have been conducted with *R. serpentina*, and the literature in scientific journals is extensive. However, because of its only recent ascendency in Western medicine, it has been generally omitted from standard pharmacological books. In the future *R. serpentina* will

probably be accorded a definite place in pharmaceutical literature, in clinics and in tropical plantations of medicinal plants.

Bibliography

(Some of the titles of the chemical papers obtained from Chemical Abstracts and the Squibb bibliography.)

Anet, F. A. L., Mukherji, D., Robinson, R., and Schlittler, E. Ajmaline. Part I. Chem. & Ind. **20:** 442. 1952.

Arnold, O. H., and Bock, K. D. New results in the pharmaceutical treatment of arterial hypertension. Deut. med. Wochschr. **78:** 879–883. 1953.

Baillon, H. Histoire des Plantes. Vol. 10: 171. 1891.

Bakshi, V. M. Determination of serpentina alkaloids. Indian Jour. Pharm. **22:** 172. 1950.

Basu, B. D. [Ed.]. Kirtikar—Indian Medicinal Plants. t. 602. 1918. [Fide Index Londinensis].

Bauhin, C. Pinax Theatri Botanici. p. 301. 1671.

Bein, H. J. Reserpin. 2. The pharmacology of reserpin, a new alkaloid from *Rauwolfia serpentina* Benth. Experientia **9:** 107–110. 1953.

Bhatia, B. B. On the use of *Rauwolfia serpentina* in high blood pressure. Jour. Indian Med. Assoc. **11:** 262–265. 1942.

——— and Kapur, R. D. Pharmacological action of alkaloids of *Rauwolfia serpentina* Benth. I. Neo-ajmaline and iso-ajmaline. Indian Jour. Med. Res. **32:** 177–182. 1944.

Bodendorf, K., Eder, H., Achelis, J. D., and Kroneberg, G. Raupin, a new alkaloid from *Rauwolfia serpentina*. Pharmacologic testing. Naturwiss. **40:** 342. 1953.

Boer, S. de. Die Wirkung von Rauwolfin auf das Herz und auf das Flimmern einer Herzabteilung. Cardiologia **1:** 1–8. 1937.

Burkill, I. H. The botany of the Abor Expedition. Rec. Bot. Sur. India **10**(2): 319. 1925.

Burman, J. Thesaurus Zeylanicus. p. 141, t. 64. 1737.

Chakravarti, M. D. Indian medicinal plant in the treatment of hypertension. Brit. Med. Jour. **1:** 1390. 1953.

Chakravarty, N. K., Chaudhuri, M. N. Rai, and Chaudhuri, R. N. *Rauwolfia serpentina* in essential hypertension. Indian Med. Gaz. **86:** 348–354. 1951.

Chatterjee, A., and Bose, S. A new alkaloid from the root of *Rauwolfia serpentina*. Sci. & Cult. **17:** 139. 1951.

Chopra, R. N. Indigenous drugs of India. p. 373. 1933.

———, Bose, B. C., and Gupta, J. C. Alkaloids of *Rauwolfia serpentina:* comparative study of their pharmacological action and their role in experimental hypertension. Indian Jour. Med. Res. **30:** 319–324. 1942.

——— and Chakravarti, M. Preliminary note on the pharmacological action of the alkaloids of *Rauwolfia serpentina*. Indian Jour. Med. Res. **29:** 763–768. 1941.

———, Das, N. N., and Mukherjee, S. N. The action of ajmaline on nerve impulses. Indian Jour. Med. Res. **24:** 1125. 1937.

———, Gupta, J. C., Bose, B. C., and Chopra, I. C. Hypnotic effect of *Rauwolfia serpentina:* the principle underlying this action; its probable nature. Indian Jour. Med. Res. **31:** 71–74. 1943.

———, ———, and Mukherjee, B. Pharmacological action of alkaloid obtained from *Rauwolfia serpentina* Benth.; preliminary note. Indian Jour. Med. Res. **21:** 261. 1933.

Chowhan, J. S. "Insanity herbs" (*Rauwolfia serpentina* Benth.). Antiseptic **39:** 26. 1942.

Ciba, Summit, N. J. Serpasil. 18 pp. [Undated: 1953 or 1954].

Cooke, T. The flora of the Presidency of Bombay. Vol. 2: 127. 1905.

Cowan, A. M., and Cowan, J. M. The trees of northern Bengal, including shrubs, woody climbers, bamboos, palms and tree ferns. p. 89. 1929.

Craib, W. G. Contributions to the Flora of Siam. Dicotyledons. p. 129. 1912.

Dalzell, N. A., and Gibson, A. The Bombay flora. pp. 143–144. 1861.

De, M. N., and Chatterjee, T. Combined digitalis and rauwolfia poisoning in human subject. Indian Med. Gaz. **76:** 724. 1941.

Deb, A. K. The role of *Rauwolfia serpentina* in treatment of mental disorders. Indian Med. Res. **63:** 359–360. 1943.

Dorfman, L., Huebner, C. F., MacPhillamy, H. B., Schlittler, E., and St. André, A. F. On the constitution of reserpine from *Rauwolfia serpentina* Benth. Experientia **9:** 368–369. 1953.

Drury, H. Handbook of the Indian flora. Vol. 2: 190–191. 1866.

Duthie, J. F. Flora of the Upper Gangetic Plain and of the adjacent Siwalik and sub-Himalayan tracts. Vol. 2: 33. 1911.

Dutt, A., Gupta, J. C., Ghosh, S., and Kahali, B. S. *Rauwolfia serpentina*. Indian Jour. Pharm. **9:** 54–57. 1947.

Dymock, W. Notes on Indian drugs. Pharm. Jour. & Trans. III. **10:** 281. 1879.

———. The vegetable materia medica of western India. pp. 420–421. 1884.

Fischer, C. E. C. A survey of the flora of the Anaimalai Hills in the Coimbatore District, Madras Presidency. Rec. Bot. Sur. India **9:** 113. 1921.

———. The flora of the Lushai Hills. Rec. Bot. Sur. India **12:** 111. 1938.

Furlenmeier, A., Lucas, R., MacPhillamy, H. B., Müller, J. M., and Schlittler, E. On the constitution of reserpine. Experientia **9:** 331–333. 1953.

Gaertner, J. Fructibus et Seminibus Plantarum. Vol. 2: 129, t. 109. 1791.

Garcin, A. G. Recherches sur les Apocynées. pp. 220–223. 1889.

Government of India, Dept. of Health. The Indian Pharmacopeial List, 1946, pp. 78–79, 157–159. 1950.

Greshoff, M. Mittheilungen aus dem chemisch-pharmakologischen Laboratorium des botanischen Gartens zu Buitenzorg (Java). Ber. Deut. Chem. Ges. **23:** 3543. 1890.

———. Nuttige Indische Planten. t. 46. 1900. [Fide Index Londinensis.]

———. *Rauwolfia serpentina* Benth. Ind. Mercuur **23:** 383–384, t. 1900.

Gupta, J. C., Deb, A. K., and Kahali, B. S. Preliminary observations on use of *Rauwolfia serpentina* Benth. in treatment of mental disorders. Indian Bed. Gaz. **78:** 547–549. 1943.

———, Ghosh, S., Dutt, A. T., and Kahali, B. S. Hypnotic principle of *Rauwolfia serpentina*. Jour. Am. Pharm. Assoc., Sci. Ed. **36:** 416. 1947.

——— and Kahali, B. S. Comparative pharmacology of the total alkaloids of *Rauwolfia serpentina* Benth. obtained from Bengal, Bihar, and Dehra Dun. Indian Jour. Med. Res. **31:** 215–219. 1943.

———, ———, and Dutt, A. The hypnotic effect of a resin fraction isolated from root of *Rauwolfia serpentina* Benth. obtained from Dehra Dun. Indian Jour. Med. Res. **32:** 183–188. 1944.

———, Roy, P. K., and Ray, G. K. A preliminary note on the excretion of *Rauwolfia* total alkaloids in urine. Indian Jour. Med. Res. **38:** 67. 1950.

Haines, H. H. The botany of Bihar and Orissa. Vol. 4: 539. 1922.

Hartog, J. Die Wirkung von Rauwolfin auf das Herz. Arch. Int. Pharmacodynamie et Therapie **51:** 10–14. 1935.

Henry, T. A. The plant alkaloids. 3rd ed. pp. 626–628. 1939.

Hensler, L. Treatment of hypertension with Serpasil, a *Rauwolfia serpentina* alkaloid. Schweiz. m. Wochschr. **83:** 1162–1166. 1953.

Heyne, K. Die nuttige planten van Nederlandsch-Indië. 2nd ed. Vol. 2: 1286–1287, 1221. 1927.

Hörhammer, L., Hänsel, R., and Rao, S. B. Zur Bestimmung der Alkaloide aus *Rauwolfia serpentina* (Benth.). Naturwiss. **39:** 553. 1952.

Hooker, J. D. The flora of British India. Vol. 3: 632. 1882.

Itallie, L. van, and Steenhauer, A. J. *Rauwolfia serpentina* Benth. Pharm. Weekblad **69:** 334. 1932.

Jacquin, N. J. Plantarum Rariorum Horti . . . Schoenbrunnensis . . . Icones. Vol. 3: 73, t. 389. 1798.

Kaempfer, E. Amoenitatum Exoticarum. Fasc. 3. Gemina Indorum Antidota. Radix Mungo. pp. 573–578. 1712.

Kapur, R. D. *Rauwolfia serpentina*—pharmacological action and its value in treatment of hyperpiesia. Jour. Indian Med. Assoc. **11:** 198–201. 1942.

———. Pharmacological action of alkaloids of *Rauwolfia serpentina*. II. Total alkaloidal extracts of Bihar and Dehra Dun varieties. Indian Jour. Med. Res. **36:** 57–60. 1948.

Khory, R. N. The Bombay Materia Medica and their therapeutics. p. 386. 1887.

King, G., and Gamble, J. S. Materials for a flora of the Malayan Peninsula. No. 19, p. 424. 1907.

Klohs, M. W., Draper, M. D., Keller, F., and Petracek, F. J. Alkaloids of *Rauwolfia serpentina* Benth. I. The characterization of reserpine and its hydrolysis products. Jour. Amer. Chem. Soc. **75:** 4867. 1953.

Koorders, S. H. Notizen über die Phanerogamenflora von Java. Nat. Tidsschr. Ned. Ind. **60:** 243. 1901.

Kress, R. Chemical and medicinal aspects of *Rauwolfia serpentina* Benth. Pharmazie **8:** 726–728. 1953.

Kurz, S. Forest flora of British Burma. Vol. 2: 171. 1877.

Linnaeus, C. Flora Zeylanica. pp. 188, 239. 1747.

———. Materia Medica. p. 168. 1749.

———. Species Plantarum Vol. 2: 1043. 1753.

Lamarck, C. de. Tableau Encyclopedique . . . Illustrations des Genres. Vol. 2 (pt. 5): t. 842. 1800. Text in Vol. 3: 423. 1823.

Mazumdar, D. C., and Mukherji, K. L. Rauwolfia in hypertension. Jour. Indian Med. Assoc. **19:** 362–367. 1950.

Merrill, E. D. An interpretation of Rumphius's Herbarium Amboinense. Publ. no. 9, Bureau of Science, Manila, p. 430. 1917.

Miquel, F. A. W. Flora Indiae Batavae. Vol. 2: 404–405. 1856.

Mookerjee, A. The alkaloids of *Rauwolfia canescens* Linn. Jour. Indian Chem. Soc. **18:** 33. 1941.

Müller, J. M., Schlittler, E., and Bein, H. J.

Reserpin, the sedative principle of *Rauwolfia serpentina* Benth. Experientia **8:** 338. 1952.

Mukherji, D., Robinson, R., and Schlittler, E. Chemistry of ajmaline, rauwolfine of Van Itallie and Steenhauer. Experientia **5:** 215. 1949.

Nairne, A. K. The flowering plants of western India. p. 179. 1894.

Nelson, J. W., and Schlagel, C. A. A preliminary note on a pharmacological investigation of the hypotensive action of *Rauwolfia serpentina* Benth. Jour. Am. Pharm. Assoc., Sci. Ed. **42:** 324. 1953.

Neuss, N., Boaz, H. E., and Forbes, J. W. Structure of reserpin. Jour. Am. Chem. Soc. **75:** 4870–4871. 1953.

Osal, A., and Farrar, G. E. The Dispensatory of the United States of America. 24 ed. p. 1569. 1947.

Paranjpe, A. S. Med. Bull. **10:** 135. 1942. [Fide Vakil.]

Parker, R. N. A forest flora of the Punjab with Hazara and Delhi. p. 331. 1924.

Pichon, M. Classification des Apocynacées II, genre *Rauvolfia*. Bull. Soc. Bot. France **94:** 31–39. 1947.

Planchon, L. Produits fournis, à la matière médical por la famille des Apocynées. pp. 237–238. 1894.

Plenck, J. J. von. Icones Plantarum Medicinalium, cent. viii, t. 732. 1812. [Fide Index Londinensis].

Plummer, A. J., Barrett, W. E., Wagle, G., and Yonkman, F. F. Sedative and hypnotic action of reserpin in unanesthetized animals. [Am. Soc. Pharmacol. Exp. Theraps., meet. 4/6–10/53]. Fed. Proc. **12:** 357–358. 1953.

Pool, J. F. A. Bijdrage tot de Kennis van den Anatomischen Bouw van de belangrijkste in Nederlandsch-oost-Indie voorkomende Vergifte Apocynaceae . . . . Pharm. Weekblad, pp. 104–110, figs. 147-150. 1928.

Prain, D. The vegetation of the districts of Hughli-Howrah and the 24-Pergunnahs. Rec. Bot. Sur. India **111:** 235. 1905.

Rama Rao, R. S. M. Flowering plants of Travancore. pp. 251–252. 1914.

Ray, G. K., Roy, P. K., Dasgupta, S. R., and Werner, G. The action of *Rauwolfia serpentina* on vasomotor reflexes. Arch. Exp. Path. Pharmakol. **219:** 310–314. 1953.

Raymond-Hamet. Sur un nouveau paralysant électif des vasoconstricteurs adrènalinosensibles l'ajmalinine, alcaloïde cristallisè de l' "Ophioxylum serpentinum" Willd. Bull. Acad. Med. [Paris] **115:** 452–458. 1936.

———. Sur quelques propriétés physiologiques de la serpentine, alcaloïde cristallisé du *Rauwolfia serpentina* Bentham. Compt. Rend. Séan. Soc. Biol. **134:** 94–96. 1940.

———. Effets intestinaux de l'ajmaline pure. Compt. Rend. Séan. Soc. Biol. **134:** 369-372. 1940.

———. Influence de la serpentinine sur les effets de l'adrènaline, de l'occulsion carotidienne et de la faradisation du pneumogastrique. Compt. Rend. Heb. Séan. Acad. Sci. **211:** 414–416. 1940.

———. Ajmaline, serpentine et serpentinine. Compt. Rend. Heb. Séan. Acad. Sci. **229:** 1165–1166. 1949.

Rheede, H. van. Hortus Malabaricus. Vol. 6: 81, t. 47. 1686.

Rose, S. Rauwolfinine, the new alkaloid of the root of *Rauwolfia serpentina* Benth. Sci. & Cult. **18:** 98. 1952.

Roxburgh, W. Flora Indica. ed. 1, Vol. 2: 530–531. 1824.

Roy, P. K. Effect of *Rauwolfia serpentina* on manic patients. Indian Jour. Neurol. & Psychiat. **2:** 59–62. 1950.

Rumphius, G. E. Herbarii Amboinensis Auctuarium. Vol. 6: 29–32, t. 16. 1755.

Salisbury, R. A. Prodromus Stirpium in Horto ad Chapel Allerton Vigentium. p. 146. 1796.

Schlittler, E., and Schwarz, H. The alkaloid serpentine from *Rauwolfia serpentina*. Helv. Chim. Acta **33:** 1463–1477. 1950.

Schroff, M. L., and Bhatia, R. L. A method of assay of *Rauwolfia serpentina*. Indian Jour. Pharm. **3:** 59–61. 1941.

Sen, G., and Bose, K. C. *Rauwolfia serpentina*, a new Indian drug for insanity and high blood-pressure. Indian Med. World **2:** 194–201. 1931.

Science News Letter. **64:** 279, 363. 1953.

Siddiqui, S., and Siddiqui, R. H. Alkaloids of *Rauwolfia serpentina* Benth. Jour. Indian Chem. Soc. **16:** 421–422. 1939. [Also **8:** 667. 1931; **9:** 539. 1932; **12:** 37. 1935. Fide Mookerjee.]

Sims, J. *Ophioxylum serpentinum*. Curtis's Bot. Mag. **20:** t. 784. 1804.

Squibb Institute for Medical Research. *Rauwolfia serpentina*. 4 pp. Additional References, 2 pp. 1953.

Squibb Institute for Medical Research. Raudixin. 26 pp. 1953.

Stachey, R. Catalogue of the plants of Kumaon and of the adjacent portions of Garhwal and Tibet. p. 110. 1906.

Stoll, A., and Hofmann, A. Sarpagin, ein neues Alkaloid aus *Rauwolfia serpentina* Benth. Helv. Chim. Acta **36:** 1143–1147. 1953.

Talbot, W. A. Systematic list of the trees,

shrubs and woody climbers of the Bombay Presidency. p. 130. 1894.

Thwaites, G. H. K. Enumeratio Plantarum Zeylaniae. p. 191. 1860.

Trapold, J. H., Osborne, M., and Yonkman, F. F. Pharmacological effects of reserpin, a new crystallized pure alkaloid from *Rauwolfia serpentina* Benth. in the dog. [Am. Soc. Pharmacol. Expt. Theraps., meet. 4/6–10/53). Fed. Proc. **12:** 373–374. 1953.

Trattinick, L. Auswahl vorzüglich schöner . . . Gartenpflanzen . . . . Vol. 2: 48–49, t. 141. 1821.

Trease, G. E. A text-book of pharmacognosy. 6th ed. p. 475. 1952.

Trimen, H. A handbook to the flora of Ceylon. Vol. 3: 126. 1895.

Vakil, R. J. A clinical trial of *Rauwolfia serpentina* in essential hypertension. Brit. Heart Jour. **11:** 350–355. 1949.

Wallis, T. E., and Rohatgi, S. The pharmacognosy of Rauwolfia. Jour. Pharm. & Pharmacol. **1:** 292–305. 1949.

Warden, C. J. H., and Bose, C. L. *Rauwolfia serpentina,* Benth. Note on certain reactions of an alkaloid contained in the roots. Pharm. Jour. & Trans. III. **23:** 101–102. 1892.

Watt, G. Dictionary of the economic products of India. Vol. 5: 489. 1891; Vol. 6: 398–399. 1892.

Wefers Bettink, H. Over den wortel van Ophioxylon serpentinum (Poeleh padak). Nieuw Tijdschr. Pharm. Nederl. **21:** 1–20. 1888.

Wehmer, C. Die Pflanzenstoffe. Vol. 2: 981. 1931. Suppl. 172. 1935.

Wendland, J. C. Bemerkungen über einige Pflanzen, nebst Abbildungen derselben. Arch. Bot. Römer **1:** 53–54, t. 7, fig. 2. 1796.

Wight, R. Icones Plantarum Orientalis. Vol. 3: 4, t. 849. 1843–1845. Vol. 4: 2. 1848.

———. Illustrations of Indian botany. Vol. 2: 162. 1845–1850.

Wilkins, R. W. New drug therapies in arterial hypertension. Ann. Int. Med. **37:** 1144–1155. 1952.

———. Current drug treatment of hypertension. Mod. Concepts Cardiovas. Dis. **22:** 198–201. 1953.

———. Hypertension: recent trends in treatment. Med. Clin. No. Amer. **37:** 1303–1312. 1953.

——— and Judson, W. E. The use of *Rauwolfia serpentina* in hypertensive patients. New Eng. Jour. Med. **248:** 48–53. 1953.

Youngken, H. W., Sr. A note on *Rauwolfia serpentina.* Am. Jour. Pharm. **125:** 186–189, fig. 1. 1953.

———. A pharmacognostical study of *Rauwolfia.* Jour. Am. Pharmaceut. Assoc., Sci. Ed. **43**(2): 70–78, fig. 1–4. 1954.

Utilization Abstracts

Candlenut Oil. This oil, obtained by cold expression from the kernels of *Aleurites moluccana*, a generic relative of the tung tree, has been utilized commercially in Australia as a satisfactory alternative to linseed oil. While candlenut seeds contain 62 to 67% of oil as compared with only 36 to 40% in linseed, the residual cake of the former, after extraction of the oil, is toxic and must seek a commercial outlet as a fertilizer instead of as a cattle feed in competition with linseed oil cake. (W. D. Raymond and Miss. J. A. Squires, *Colonial Plant and Animal Products 3(3): 229. 1952–3*).

Cloves in Cigarettes. In Indonesia a type of cigarette manufactured and smoked only there and known as " kretek " is distinguished by its containing shredded cloves, or " tjenkeh ", an ingredient which causes a crackling effect during burning. Cloves imported from Zanzibar, instead of locally grown material, are used for this purpose, and when the Zanzibar clove harvest failed in 1952, about 200,000 workers in the Indonesian kretek industry became unemployed.

" Originally, this type of cigarette consisted of an outer wrapper of either dried maize leaf, dried banana leaf or dried palm leaf which was filled with a mixture of native shag tobacco and shredded cloves (10 parts of tobacco to 6 parts of cloves). The modern cigarette is machine-made and has the usual paper wrapper. The general method of adding the cloves as practised by the large cigarette manufacturers is to cut the cloves into 20 or 30 small pieces, but the smaller manufacturer grinds the cloves for mixing with the tobacco ". (*Colonial Plant and Animal Products 3(3): 252. 1952–3*).

Indian Aconites

Of the two dozen species of aconite native to India, thirteen are known to possess drug value. Some of the latter are in commercial trade and offer valuable substitutes for the more commonly used species of Europe. Their nomenclature is revised in this article, with proper consideration given to their habitats and chemical constituents in order to facilitate identification and standardization of this drug.

H. L. CHAKRAVARTY AND D. CHAKRAVARTI

Departments of Botany and Chemistry, respectively, Presidency College, Calcutta

Introduction

The drug Aconite, known since ancient times, is the unground or powdered tuberous root of several species of *Aconitum*. This herbaceous genus, consisting of about 110 species and belonging to the family Ranunculaceae, is distributed in many parts of the world. A paste of the mashed tubers was a famous arrow poison of the ancient Chinese, and the name " aconite " is derived in all probability from the Greek word " akwan ", a dart.

The official drug in modern medicine is obtained from *Aconitum napellus* L., a large group of plants consisting of numerous sub-species, varieties, clons and forms, and collected from the wild in the cooler regions of Germany, Spain, Switzerland and Russia. Among many medicinal uses of the drug are external application of it in treating neuralgia and rheumatism, and internal administration to relieve fever and pain.

Among the many other species which also are poisonous and possess therapeutic qualities are those native to the temperate zone in the western Himalayas of India. Aconite is mentioned in old Hindu medicine as " ativisa ", which means a deadly poison that neutralizes the effect of another poison. In olden days it was of common use in India, for the drug was known in all provinces of the country, and the various names applied to it bore the same meaning as " ativisa ".

In the eighth century, when the Arabs translated Susruta Samhita, they introduced the Indian aconites into their Pharmacopoeia and listed them as " visa " (poison). Ebu Baithar was probably the first Arab writer who mentioned that visa was a plant growing in India. Muwaffak described " halahill " as one kind of visa which was so poisonous that a quantity smaller than a mustard grain was enough to kill a man. Moreover, he referred to an author, Isa Ben Ali, who said that halahill grew in a region known as Tehri-Garhwal and farther east. Christoval Acosta travelled in India about the middle of the sixteenth century and mentioned Central Himalaya as the home of Indian aconites.

Taxonomy and Nomenclature

In 1802 Hamilton went to Nepal and reported on aconites growing there: " This dreadful root, of which larger quantities are annually imported, is equally fatal when taken into the stomach and applied to wounds, and is in universal use for poisoning arrows. . . . The Gorkhalese pretend that it is one of

their principal securities against invasion from low countries and they would so infect all waters on the route by which an enemy was advancing as to occasion his certain destruction ". In 1817, Wallich also collected specimens of aconites from Nepal, and in 1848 Hooker got some from an altogether different region in Sikkim. Later Watt had his collection of plants. He recognized the existing confusion in the nomenclature of aconite species of India and remarked that some of them were poisonous and others were not. He noted that the poisonous species which had drug value needed to be identified properly, for otherwise an exported quantity might be useless. Hanbury and Oliver emphasized the necessity of precise knowledge concerning Indian aconites before exporting them, and Brühl and King took up the study on specimens regarded as being *A. ferox*.

In 1905 Stapf classified the genus as it existed in India, and on the basis of root structure he arranged the species in three sections: Gymnaconitum, having annual roots; Lycoctonum, possessing perennial roots; Napellus, with biennial roots. The majority of species fell into the Napellus section, and this section was therefore divided into three sub-sections with reference to their anatomy: true Napellus, with continuous cambium; Anthora, with up to six discontinuous concentric rings or irregular batches of cambium embedded in uniform tissue; Deinorrhizum, with isolated bands of cambium embedded in secondary phloem.

While Stapf's arrangement of aconites is followed in the present treatment, it must be stated that his classification has not escaped objection. It is based on anatomical features, and such features can seldom be considered good diagnostic characters, since soil structure, water content, climate and other ecological factors in most cases influence the internal structure of plants. Nevertheless the system serves our purpose, and of the known 110 or so species distributed throughout the world, the two dozen native to India are listed in Table I. Description of the economic species treated under each heading has been thoroughly revised by the author (H. L. C.).

TABLE I

INDIAN SPECIES OF *Aconitum*

Section	Species
I. Gymnaconitum	1. *A. gymnandrum*
II. Lycoctonum	2. *A. leave* 3. *A. luridum* 4. *A. moschatum*
III. Napellus	
Subsection (i) Napellus	5. *A. soongaricum* 6. *A. chasmanthum* 7. *A. violaceum* 8. *A. falconeri* 9. *A. spicatum* 10. *A. laciniatum* 11. *A. ferox* 12. *A. heterophylloides* 13. *A. leucanthum* 14. *A. dissectum*
Subsection (ii) Anthora	15. *A. elwesii* 16. *A. lethale* 17. *A. nagarum* 18. *A. rotundifolium* 19. *A. heterophyllum* 20. *A. naviculare* 21. *A. palmatum* 22. *A. hookeri*
Subsection (iii) Deinorrhizum	23. *A. deinorrhizum* 24. *A. balfourii*

Of the foregoing 24 species, the thirteen known to possess drug value are identified in Table II and described in detail on subsequent pages.

1. *Aconitum luridum* Hook. f. & Thom.

Root perennial, descending, cylindric. Stem erect. Leaves few, palmately lobed; blade orbicular-cordate or reniform; petiole long; lobation of leaves and length of petiole decreasing upward. Inflorescence racemose, up to 40 cm. long, narrow, dense. Sepals lurid, red-

TABLE II

Key to the Indian Aconite Species of Drug Value

A. Root perennial, long, fusiform, usually breaking up at length into cord-like anastomosing or free strands; old plants often with several stems from the collar (Section I. Lycoctonum)	1. *A. luridum*
AA. Root biennial, paired, tuberous; each tuber producing normally one simple or (rarely) branched stem (Section II. Napellus)	
B. Stem erect, rarely ascending, never twining	
C. Seed-angles winged, faces smooth or almost so (not transversely lamellate)	
D. All the leaves distinctly to very long-petioled, cordate-orbicular or reniform in outline, deeply dissected, cambium of tuber continuous, forming a sinuous ring; honey-gland on back of nectary hood	
E. Tubers 2–3.5 cm. long, fracture (in the dry state) horny or cartilaginous, brown, taste slightly bitter, followed by a tingling sensation; carpels 5, glabrous or nearly so, never tomentose	2. *A. chasmanthum*
EE. Tubers 0.5–2.5 cm. long, fracture (in the dry state) almost farinaceous, pure white; taste indifferent or slightly sweetish, not followed by any tingling sensation; carpels densely tomentose	3. *A. violaceum*
DD. All the leaves with the exception of the lowest shortly petioled to subsessile, cordate-ovate, coarsely crenate, cambium of tuber discontinuous	4. *A. heterophyllum*
CC. Seeds with hyaline wavy transverse lamellae	
D. Cambium of tubers discontinuous, horseshoe-shaped in t.s.	
E. Inflorescence and carpels almost glabrous and never yellowish tomentose, leaves divided	
F. Nectar-hood very slender with a minute lip; carpels glabrous, taste of tuber bitter, but with no tingling sensation	5. *A. palmatum*
FF. Nectar-hood leaning forward; lip short and broad; emarginate carpels greyish pubescent, tuber with strong tingling sensation	6. *A. deinorrhizum*
EE. Inflorescence and carpels yellowish tomentose; leaves less divided	7. *A. balfourii*
DD. Cambium of tubers continuous, sinuous in t.s.	
E. Secondary phloem in tubers not encased in sclerenchymatous sheath; lip of nectary wide; leaf-segments rarely and inconspicuously divaricate	
F. Leaves divided to $\frac{6}{7}$ part in the inner to $\frac{3}{4}$ part or less in the outer incisions, ultimate division rather broad; carpels 5; follicles 10–18 mm. long	
G. Intermediate leaf-division mostly ovate in outline, sparingly and coarsely inciso-crenate; nectary-hood much leaning forward, slightly widened at the top, scarcely gibbous; carpels glabrous or nearly so; follicles 14–18 mm. long	8. *A. falconeri*
GG. Intermediate leaf-division mostly ovate in outline, copiously inciso-crenate or dentate; nectary-hood slightly leaning forward, distinctly gibbous at the top; carpels villous; follicles about 10 mm. long	9. *A. spicatum*
FF. Leaves divided almost to the very base, ultimate divisions narrow; carpels mostly 3; follicles 18–25 mm. long	10. *A. laciniatum*
EE. Secondary phloem of tubers encased in sclerenchymatous sheath; lip of nectary narrow; leaf-segments conspicuously divaricate	11. *A. ferox*
BB. Stem very slender, twining	
C. Flowers on recurved pedicels nodding up to 5 cm. long; helmet conic-ovate in profile	12. *A. elwesii*
CC. Flowers on straight or almost straight pedicels up to 7.5 cm. long; helmet depressed, semi-orbicular in profile	13. *A. lethale*

dish or brownish-red; upper sepal helmet-shaped, broad, semi-elliptic, gradually narrowing into an obtuse beak; lateral sepals obliquely obovate; lower ones deflexed, oblong. Nectaries hammer-shaped, hood at right angle to the claw, lip horizontal, slightly 2-lobed. Carpels 3, contiguous. Follicles 10–12 mm. long, erect, contiguous, oblong, subtruncate. Seeds up to 3 mm. long, triquatrous, oblong, blackish-brown, unequally winged.

The root is reputedly poisonous.

HABITAT. Himalayas from eastern Nepal to Chumbi, between 12,000 and 14,000 ft.

2. *Aconitum chasmanthum* Stapf ex Holmes

Roots biennial, paired, tuberous; daughter tubers conic, brown to blackish-brown, smooth or wrinkled when dry; fracture cartilaginous; hard; taste bitter, followed by a persistent strong tingling sensation; cambium continuous, forming a wide central strand, sinuous in cross section. Leaves numerous, usually more distant in the lower part, petiole 7.5 cm. long, the upper shortly petioled or subsessile, glabrous, somewhat fleshy, lower and intermediate blades orbicular, reniform in outline, segments palmatifid to palmatripartite from the apex to the base of the plant. Inflorescence a long, narrow, stiff, dense or loose raceme, often over 30 cm. long; pedicels slender, up to 3.5 cm. long. Sepals blue or whitish and variegated with blue, crispo-pubescent or almost glabrous; upper helmet-shaped, depressed into a slender beak; lateral sepals not contiguous with the helmet except near the base, obliquely suborbicular or almost square, shortly or obscurely clawed; lower sepals oblong, obtuse. Nectaries extinguisher-shaped, glabrous; claw 5–6 mm. long, leaning forward in the upper part; hood short, wide, very obtuse; honey gland at the top of the gibbous back of the top. Stamens many, filaments almost glabrous, winged. Carpels 5, glabrous, abruptly contracted into a short style, back convex. Follicles oblong, truncate, 10–16 mm. long, contiguous or with slightly divergent tips, glabrous. Seeds brown, obovoid to obpyramidal, 3.5 mm. long, unequally 3-winged; wings thin, faces smooth.

HABITAT. Subalpine and alpine zone of the western Himalayas from Chitral and Hazara to Kashmir, between 7,000 and 12,000 ft.

The Indian *A. chasmanthum* is likely to be confused with the European species (*A. napellus*), especially when dry specimens are compared. The distinguishing features are as follows:

A. chasmanthum	*A. napellus*
1. Tuber smaller, shorter and thicker.	1. Tuber not so thick.
2. Leaves smaller, lower ones long-petioled and divided into narrower segments.	2. Petiole not so long, blade not so narrowly divided.
3. Racemes long and very slender.	3. Racemes stout.
4. Flowers small, usually blue and white.	4. Flowers large, dark to bluish-purple.
5. Helmet rostrate, depressed, widely gapping.	5. Helmet laterally compressed, pointed, not much gapping.
6. Carpels 5, conniving, suddenly contracted into style.	6. Carpels 3, quite distinct, beaked by recurved style.
7. Mature pedicels and fruits tightly adpressed to the rachis.	7. Not adpressed.
8. Seeds smaller and lighter, 650 seeds to 1 gm., approximately.	8. Seeds heavier, 250 seeds to 1 gm., approximately.

3. *Aconitum violaceum* Jacquemont

Root biennial, paired, whitish to brown, smooth fracture pure white, slightly sweetish, not followed by any tingling sensation. Stem erect. Leaves very few, orbicular cordate or reniform, 5-palmati-partite. Inflorescence a short, lax or dense few-flowered raceme or corymb or reduced to a solitary flower. Sepals violet, blue or yellowish and variegated with blue, pubescent; uppermost helmet-shaped or almost navicular, obliquely erect, somewhat depressed; lateral sepals contiguous; lower sepals deflexed. Nectaries extinguisher-shaped, claw erect, leaning forward, lip broad, truncate, filaments finely and rigidly hairy in the upper part, winged below. Carpels 5, conniving, contiguous, densely tomentose. Follicles oblong, truncate, erect, contiguous, 10–12 mm. long densely hairy. Seeds 3-gonous, 2.5–3 mm. long, angles winged.

HABITAT. Alpine zone of the Himalayas from Gilgit to Kumaon, between 10,000 and 15,000 ft.

4. *Aconitum heterophyllum* Wall

Root biennial, paired, tuberous; daughter tuber cylindric to cylindric-oblong or conic, 2–5 cm. long, bearing a few root fibers; bark thin, whitish or grey, smooth; fracture pure white, farinaceous; cambium discontinuous, forming usually 4 or 5 isolated slender cylindric strands arranged in a ring; taste purely bitter. Leaves more or less heteromorphous, glabrous or the upper sparingly pubescent on the nerves below; the lowest on long petiole; blade orbicular-cordate or ovate-cordate; intermediate leaves shortly petioled or sessile, ovate-cordate, often acuminate; uppermost leaves similar to the preceding, amplexicaul. Inflorescence a slender raceme or a lax leafy panicle. Sepals more or less blue or violet, rarely whitish, with dark conspicuous veins; upper sepals almost navicular; obliquely erect, shortly or obscurely beaked, 18–20 mm. high, lateral margins sinuous; lateral sepals very oblique and broadly ovate with dark tips; lower sepals elliptic, obtuse or subacute. Nectaries glabrous, extinguisher-shaped; claw erect, 16–18 mm. long; hood short and very wide, more or less gibbous above; lip very short and broad, obtusely 2-lobed or entire. Filaments 6–8 mm. long, winged beyond the middle, usually abruptly contracted, rarely produced into short teeth. Carpels 5, contiguous, elliptic-oblong, shortly contracted into the slightly shorter style, crispo-pubescent with depressed hairs. Follicles 16–18 mm. long, contiguous, linear oblong, straight. Seeds 3–4 mm. long, obpyramidal, blackish-brown, angles acute or more or less winged, faces smooth.

HABITAT. Common in the sub-alpine alpine zones of the Himalayas, from Indus to Kumaon, occurring at altitudes between 6,000 and 15,000 feet, very plentiful in the neighbourhood of Simla, very common in the Sach pass, Chamba, at 7,000–15,000 ft.

ADULTERANTS AND SUBSTITUTES. This root is said by O'Shaughnessy to be adulterated with that of *Asparagus racemosus* (Satamuli). Two kinds of roots are met with in the market—(*a*) grey, shrivelled tubers, large and longer than (*b*) white, the daughter offshoots broken from the former. The latter fetch the best price.

5. *Aconitum palmatum* D. Don

Biennial herb. Root paired, tuberous, fracture horny, brownish; cambium discontinuous, bitter. Stem erect, sometimes slightly flexuous in the upper part, simple or nearly so, 2–5 feet. Leaves scattered, rather distant, up to 10, rarely more, glabrous; petiole slender; blade obicular-cordate to reniform with a very wide sinus. Inflorescence very loose, leafy panicle or raceme. Sepals bluish or variegated white or blue; uppermost

Upper left: *Aconitum balfourii* Stapf. Upper right: *Aconitum ferox* Wall. ex Seringe. Lower left: *Aconitum heterophyllum* Wall. Lower right: *Aconitum palmatum* D. Don. Half natural size.

helmet-shaped, helmet obliquely semi-orbicular, very shortly beaked, lateral sepals contiguous with the helmet, lower sepals obliquely oblong or elliptic. Nectaries extinguisher-shaped, claw erect, lip very short. Filaments glabrous, narrowly winged to or below the middle. Carpels 5, sub-contiguous in the flower but soon diverging. Follicles 5, 2.5–3 cm. long, sub-contiguous or somewhat diverging in the upper part. Seeds blackish, obovoid, about 3 mm. long, obscurely winged along the raphe, transversely lamellate.

The root contains the non-toxic alkaloid palmatisine.

HABITAT. Alpine Himalaya of Nepal, Sikkim and the adjoining part of South Tibet from 10,000 to 16,000 ft.

6. *Aconitum deinorrhizum* Stapf

Root biennial, tuberous, paired; daughter tuber conical, rather elongated, up to 6.5 cm. long, at the upper end up to 18 mm. thick; fracture scarcely farinaceous; whitish; taste indifferent, followed by a strong tingling sensation; cambium discontinuous, broken into strands arranged in a ring, the smaller circular in cross section, the larger tangentially flattened. Mother tuber similar, more or less shrunk, wrinkled, with long filiform root fibres. Stem several feet high, erect, straight, simple, terete, sparingly and finely crispo-pubescent in the upper part, otherwise glabrous; shining, or in young parts sparingly pubescent. Leaves 10–12, scattered, lower usually decayed at the time of flowering; petiole slender, mostly 5–7 cm. long, dilated at the base; blade reniform or ovate reniform in outline, with a wide sinus or an almost truncate base, 5-pedate partite almost to the base. Inflorescence straight, racemose, 30–40 cm. long, not very dense; sepals blue, uppermost helmet-shaped, more or less obliquely depressed, slightly concave towards the base in front and extended into a short beak, shortly and broadly clawed; lateral oblique, suborbicular, scarcely unguiculate, ciliate. Nectaries hispidulous all over, claw almost straight; hood leaning forward, gibbous near the top, lip short, broad, emarginate. Stamens many, filaments hairy on the upper part, winged beyond the middle. Carpels 3, oblong, greyish-pubescent, style long. Follicles unknown. Seeds 3 mm. long, obconic, with numerous small short transverse lamella.

The root contains the poisonous alkaloid pseudaconitine.

HABITAT. Alpine Himalaya of Bashahr.

7. *Aconitum balfourii* Stapf

Root biennial, paired or ternate, tuberous; daughter tubers sometimes divided from the base, conic or elongate, 3–7 cm. long, externally greyish-brown; fracture white; almost horny; taste indifferent, followed by a tingling sensation; cambium discontinuous, strands arranged in a ring, smaller circular and larger horseshoe-shaped in transverse section. Stem erect, more or less glabrous. Leaves 6–10, palmately divided, segmentation less pronounced than in other species, ultimate divisions small, orbicular or ovate-cordate or subreniform; petiole 7.5 cm. long; blade 10–12 cm. long. Inflorescence racemose, up to 30 cm. long, many-flowered, dense. Sepals 5, petaloid, blue, pubescent; upper helmet-shaped, oblique; lateral sepals sub-oblique; lower elliptic. Nectaries glabrous, hood leaning forward. Stamens many, filaments almost glabrous. Carpels 5, yellowish tomentose. Follicles up to 12 mm. long, oblong, slightly divergent above, contiguous below. Seeds 3–3.5 mm., trigonous, slightly winged, with narrow transverse lamellae giving out towards the back.

HABITAT. Subalpine and alpine Himalaya from British Garhwal to Nepal.

8. *Aconitum falconeri* Stapf

Roots biennial, paired, tuberous; daughter tuber conic to cylindric from a broad truncate base, up to 8 cm. long to 2 cm. thick; entire or divided, bearing root fibres externally; brown, fracture white, slightly farinaceous or horny; taste somewhat bitter followed by a strong burning and tingling sensation; cambium continuous, sinuous in transverse section; mother tuber much shrunk and wrinkled. Leaves scattered, 10 or more; if many, the upper sometimes crowded; petiole slender, lowest up to 12 cm.; blade rotundo-cordate to reniform in outline, palmately lobed to dissected. Inflorescence a dense raceme 15–20 cm. long. Sepals blue with very dark tips, pubescent; uppermost helmet-shaped, helmet obliquely semi-orbicular in profile, very shortly beaked; lateral sepals oblique, sub-orbicular or ovate orbicular; lower sepals oblong elliptic, obtuse. Nectaries extinguisher-shaped, claw erect, hood leaning forward or almost horizontal. Carpels 5, obliquely oblong, conniving in the flower, divergent when mature, silky pubescent, black when dry. Follicles erect and contiguous or slightly diverging upwards. Seeds brown, obconic winged along the raphe, with wide and transverse lamellae.

HABITAT. Subalpine and alpine zone of the Himalaya of Garhwal.

9. *Aconitum spicatum* Stapf

Roots biennial, paired, tuberous, brown or blackish-brown; fracture horny; yellowish or brownish in dry state; slightly sweetish bitter, followed by a tingling sensation; cambium continuous. Stem erect, glabrescent. Leaves 5–8, orbicular-cordate, palmately lobed. Inflorescence racemose or often panicled. Sepals blue; uppermost helmet-shaped, helmet erect or slightly oblique, depressed, semi-orbicular; lateral sepals oblique, suborbicular; lower horizontal or deflexed. Nectaries glabrous, claw slightly curved or straight. Filaments winged to or beyond the middle. Carpels 5, oblong, contracted into the slightly shorter style, densely tomentose. Follicles 5, oblong, contiguous, about 15 mm. long. Seeds obpyramidal, about 4 mm. long, winged along the raphe, with undulate hyaline transverse lamellae.

HABITAT. Alpine zone of the Himalaya of Sikkim and Chumbi.

10. *Aconitum laciniatum* Stapf

Root biennial, tuberous; paired; daughter tuber conic oblong, brown; fracture whitish; almost horny; taste indifferent or very slightly bitter, followed by a tingling sensation; cambium continuous, forming a sinuous ring in cross section. Stem erect. Leaves scattered, reniform, palmately lobed. Inflorescence racemose or loosely paniculate. Sepals red purple or red dark; uppermost helmet-shaped; lateral sepals oblique; suborbicular; lower deflexed or sub-horizontal, oblong, obtuse. Nectaries hispidulous; claw slightly curved; hood suberect gibbous or spurred on the back. Filaments hispidulous; winged to or beyond the middle. Carpels 3, rarely 4 or 5, conniving in the flower, oblong. Follicles 18–25 mm. long, at first divergent, then conniving, contiguous. Seeds obpyramidal, 3-gonous, 3 mm. long, with transverse hyaline lamellae.

HABITAT. Subalpine and alpine Himalaya of Sikkim adjoining Tibet, between 10,000 and 14,000 ft.

11. *Aconitum ferox* Wall. ex Seringe

Roots biennial, paired, tuberous; daughter tuber ovoid-oblong to ellipsoid, 2.5–4 cm. long, with filiform root fibres, dark brown; fracture yellowish; taste indifferent with strong tingling sensation; cambium continuous, forming in cross section a slightly sinuous ring; outer sieve-strand surrounded by a mantle of

sclerenchymatous cells. Stem erect, glabrous below, hollow. Leaves scattered, distant; petiole slender, up to 25 cm. long; blade orbicular-cordate to reniform with a rather wide sinus, palmatifid to partite from younger to the older leaves. Inflorescence a loose raceme, 10–25 cm. long. Sepals blue, hairy; uppermost helmet-shaped, helmet semiorbicular in profile, shortly beaked, 20–24 mm. high; lateral sepals slightly contiguous; lower sepals deflexed, oblong, sub-acute, 10 mm. long. Nectaries glabrous; claw erect; hood oblique to sub-horizontal, oblong; tip deflexed, lanceolate, acute entire. Stamens many, filaments glabrous, about 7 mm. long, narrowly winged, wings gradually attenuate. Carpels 5, conniving and contiguous, tomentose, gradually passing into the style. Follicles oblong, obliquely sub-truncate, 15–20 mm. long, dorsally sub-convex, loosely tomentose or almost glabrous, conspicuously reticulate. Seeds 2.6–3 mm. long, obovoid to obpyramidal, winged along the raphe, transversely lamellate on the faces, lamellae undulate.

HABITAT. Alpine Himalaya of Nepal.

12. *Aconitum elwesii* Stapf

Roots unknown. Stem scandent. Basal leaves unknown; intermediate and upper scattered petioled; petioles flexuous; blade cordate-ovate or rotundate in outline. Inflorescence axillary or terminal racemose, or sub-paniculate, pendulous or nodding, few to many-flowered; sepals blue or violet, sparingly pubescent; uppermost helmet-shaped, helmet broadly semi-elliptic; lateral ones sub-orbicular, sub-oblique; lower deflexed oblong, obtuse. Nectaries glabrous; claw slightly curved; hood sub-erect recurved spurred. Filament 6 mm. long, winged to or beyond middle. Carpels 5, conniving, glabrous, obliquely oblong. Follicles 5, 14–18 mm. long, divergent, oblong, up to 12 mm. long. Seed unknown.

HABITAT. Alpine Himalaya of North-Eastern Sikkim.

13. *Aconitum lethale* Griffth

Root fusiform, whitish or brown. Stem scandent, branched, flexuous, slender. Leaves scattered, cordate-rotundate, palmately lobed. Inflorescence loosely racemose; bracts foliaceous, 3-lobed. Sepals blue; uppermost helmet-shaped, helmet semiorbicular-elliptic; lateral orbicular-obovate; lower deflexed, broad elliptic, subobtuse. Nectaries glabrous, claw erect; hood erect. Filaments glabrous, winged to or beyond middle. Carpels 5, obliquely oblong, sparingly pubescent.

HABITAT. Higher parts of Mishmi mountains, Assam.

Of the preceding 13 species of Indian aconite known to possess therapeutic qualities, those which contribute to actual commercial supplies are indicated in Table III.

TABLE III

INDIAN ACONITES OF COMMERCIAL VALUE

1. *A. heterophyllum:* non-poisonous; contains atisine.
2. *A. chasmanthum:* formerly thought to be *A. napellus;* contains indaconitine. True *A. napellus* is imported in India.
3. *A. ferox:* the authentic species is rarely found in the market, being more or less confined to the Nepal region of the Himalayas. The *A. ferox* of the market is an indiscriminate mixture of *A. deinorrhizum, A. balfourii, A. spicatum* and *A. laciniatum.*
4. *A. lycoctonum:* in reality either *A. leave, A. luridum* or *A. moschatum,* or a mixture of them.
5. "Nepal Aconite" is a mixture of *A. laciniatum* and *A. spicatum.*

Chemistry

Aconite roots contain a mixture of alkaloids. Six of those in the Indian species have been named and their chemical structures determined, as indi-

TABLE IV

ALKALOIDS OF INDIAN ACONITES

Species	Alkaloids	Molecular formula	m.p.		P.C. of alkaloids
A. balfourii	Pseudo-aconitine	$C_{36}H_{51}O_{12}N$	212–13	17.06 (EtOH)	.51
A. chasmanthum	Indaconitine	$C_{34}H_{47}O_{10}N$	202–03	18.3 (EtOH)	4.5
A. deinorrhizum	Pseudo-aconitine	....	......	....	.51
A. spicatum	Bikhaconitine	$C_{36}H_{51}O_{11}N \cdot H_2O$	113–16	12.21 (EtOH)	...
A. heterophyllum	Atisine	$C_{22}H_{33}O_2N$	57–60	....	.38
"*A. lycoctonum*"	Lycoctonine	$C_{20}H_{33}O_5N \cdot H_2O$	139	....	...

cated in Table IV. With age, high temperature, moisture and storage, these alkaloids undergo changes in their chemical composition, so much so that samples preserved for long have been found to contain little or no active principle at all.

The three classes of chemical compounds, alkaloids, glycerides and volatile oils, are often of value in the classification of plants. For instance, the name *Lycopodium clavatum* was at one time applied to forms of club moss growing in both Europe and North America. From the European plant, however, the three alkaloids lycopodine, clavatine and clavatoxine were obtainable, whereas in the American plant, growing in Canada, only lycopodine was detected. According to Manske, this appeared to call for revision, of the nomenclature of the plants growing in the two regions for there remained the disconcerting possibility that varietal distinctions or habitat have a profound influence on the nature of the elaborated alkaloids. In this genus *Aconitum* the apparently identical species *A. deinorrhizum* and *A. spicatum* are similarly distinguishable by their alkaloids, pseudo-aconitine and bikhaconitine, respectively. Some Japanese species originally labeled as *A. fischerii* were subsequently distinguished as *A. japonicum* on the basis of alkaloid

TABLE V

BIOLOGICAL ASSAY OF INDIAN ACONITES

Alkaloids of	Weight of guinea pig	Dose in cc. 1 in 10,000	Results	Dose in gm. per gm. wt.
	gm.	*cc.*		
1. *A. chasmanthum*	337	0.202	Alive over 24 hrs.	0.000,000,06
2. "	396	0.315	do	0.000,000,008
3. "	380	0.380	Died after 1 hr.	0.000,000,1
4. "	405	0.344	Died after 2 hrs.	0.000,000,085
5. "	375	0.307	Died after 24 hrs.	0.000,000,825
1. "*A. ferox*", *i.e.*, a mixture of *A. deinorrhizum* and *A. balfourii*	345	0.210	Died after 2½ hrs.	0.000,000,06
2. "	370	0.148	Alive over 24 hrs.	0.000,000,04
3. "	340	0.170	Died after 2 hrs.	0.000,000,05
4. "	385	0.160	Died after 2½ hrs.	0.000,000,045
A. heterophyllum	400	2 cc. of 1 in 100	Alive over 24 hrs.	....

content, *A. fischerii* being characterized by japaconitine ($C_{34}H_{49}O_{11}N$), *A. japonicum* by jesaconitine ($C_{35}H_{49}O_{12}N$).

In standardising aconite, it has been found that chemical methods indicate only total alkaloids, both physiologically active and inactive, whilst in biological assay the presence of only the physiologically active alkaloids, such as pseudoaconitine and indaconitine, is indicated. Some results of biological assay are shown in Table V. The active alkaloids of the so-called " A. ferox " of the Indian market have a lethal dose of 0.000,000,045 gm. per gm. weight of guinea pig. For the bases of *A. chasmanthum,* the dose is about 0.000,000,1 gm. per gm. weight. That is, the bases of " A. ferox " are 1.5 times as active as those of *A. chasmanthum* and 0.7 as strong as the alkaloid aconitine from the European species, *A. napellus.* It appears, therefore, that the Indian aconites are good substitutes for the European. The so-called " A. ferox " is easily procurable in quantity from Indian markets, and the tubers of " A. ferox " are distinct, for they are often fasciculated (2–3), two to five inches long, three-quarters to one inch in diameter, with thick cuticle and coloured either dark brown or black.

Acknowledgment

The writers acknowledge the help of Professor Ramgopal Chatterjee, Department of Chemistry, Presidency College, Calcutta, in the assay of aconite alkaloids and in preparing the manuscript.

Literature Cited

Brühl, P., and King, G. A century of new and rare Indian plants. Ann. Royal Bot. Gard., Calcutta 5: 71-170. 1896. [p. 109–114].

Chopra, R. N. Indigenous drugs of India. p. 47. 1939.

Coun. Sci. and Ind. Res. The wealth of India. Vol. 1: 24–28. 1948.

Hamilton [*formerly* Buchanan Francis]. Account of the Kingdom of Nepal. p. 98–100. 1819.

Henry, T. The plant alkaloids. p. 673. 1949.

Stapf, O. The aconites of India. Ann. Roy. Bot. Gard., Calcutta 10(2): 115–197. 1905.

Watt, G. Dictionary of economic products of India. p. 86–98. 1889.

———. Commercial products of India. p. 18–24. 1908.

Utilization Abstracts

Bambara Groundnuts. These leguminous seeds, known also as " Madagascar peanuts ", " Juga beans " and " earthnuts ", are produced, like true peanuts, in underground pods. The plants (*Voandzeia subterranea*) occur fairly generally throughout tropical Africa where they are widely cultivated, often in rotation with maize and sorghum. The nuts, either green or ripe, are used for human consumption in Africa and the Far East, and, after soaking, are fed to livestock. (Miss R. M. Johnson, *Colonial Plant and Animal Products 4(1): 76. 1954*).

Caesalpinia Tannin. Three species of *Caesalpinia* are established commercial sources of tannin:

C. coriaria. Known as " divi-divi " and " libi-libi ", this one is indigenous to many parts of South America and has been introduced into many other countries. Commercial divi-divi is derived almost entirely from tropical South America, only small quantities being exported from India and Jamaica. The pods contain 40–50% of easily leached tannin.

C. brevifolia. Known as " algarobilla " and obtained mainly from Chile and Peru. Unsuccessful attempts have been made to cultivate this species in certain parts of Africa, India and Cyprus. Pods contain 45–60% tannin.

C. spinosa. Known as " tara " and widely distributed in northwestern South America. The pods contain 35–55% tannin.

In addition to the foregoing, other species of *Caesalpinia* in Mexico and Ecuador have been used to some extent, as well as one thorny shrub of India. (F. N. Howes, *Materiae Vegetabiles 1(1): 60. 1952*).

Flavor Qualities of Some Edible Oriental Bamboos

Sixteen kinds of bamboo shoots are here classified on the basis of their acridity, and recipes given for preparation of them as articles of food.

ROBERT A. YOUNG [1]

Introduction

Fresh shoots of 16 species and varieties of bamboo, belonging mainly to the genus *Phyllostachys*, were tested both raw and cooked by the writer in the spring of 1953. Nearly all were grown at the Savannah, Ga., Plant Introduction Garden of the Division of Plant Exploration and Introduction, U. S. Department of Agriculture. The shoots were selected in late April by Dr. Floyd A. McClure, bamboo specialist of the Foreign Agricultural Service of the Department, who at the time was making certain studies of the bamboos at the Garden; they were prepared with the collaboration of Mr. David A. Bisset, in charge of the Garden, for shipment to the Division Headquarters at the Plant Industry Station, Beltsville, Maryland.

The chief reason for recording the taste of the raw shoots is that, even among edible bamboos, most have more or less of a characteristic unpleasant flavor, or " bite ". Strictly speaking, this " bite " is neither bitter nor astringent; it might, perhaps, be termed " acrid ". Dr. McClure has suggested that the causal substance may be enzymic. A fact for consideration in this connection is that, whatever it is, the substance is not quickly destroyed by a boiling temperature, especially where the acridity in the raw shoot is pronounced. Investigation of the nature of the substance or substances that cause the disagreeable flavor should sometime be undertaken by a suitably equipped agency.

Except in four species of the bamboos tested, I detected no distinctive flavor or odor, and the differences in edible qualities among the remainder were essentially in the relative strength or absence of the slightly acrid taste and in the degree of tenderness of the cooked shoots. Differences in tenderness or freedom from fiber were apparently due almost entirely to the stage of development of the shoot or to the distance from the tip of the shoot of the part tested. However, it would seem that the young shoot of a bamboo of which the wood of the mature culm is unusually dense, might well be somewhat firmer than shoots of others, and careful, planned testing might show this to be true. Shoots in comparable stages of development would have to be selected.

Categories According to Flavor

The bamboos whose shoots were tested are listed below in three categories, according to the degree of acridity or " bite " in the raw shoots as tested by myself. The ratings between shoots with a small degree of acridity and those with greater must not be assumed to be precise, since one's perception becomes

[1] Collaborator, Division of Plant Exploration and Introduction, Agricultural Research Service, United States Department of Agriculture. All photographs used are from the Department.

This article was received prior to the recent reorganization of the United States Department of Agriculture. The Division of Plant Exploration and Introduction is now known as the Section of Plant Introduction.

FIG. 1. Sprouts of an edible bamboo (*Phyllostachys bambusoides* Sieb. & Zucc.) in different stages of preparation, variously sliced for cooking. Bamboo shoots for the table are best dug at about the stage of development of the shoot shown in the natural state above. In preparation the heavy sheaths are first stripped off and the basal part of the shoot discarded because of woody tissue.

somewhat blurred after tasting within a short period several samples that are acrid, even though some are but slightly so. For purposes of record nearly all the items are listed under the Division's plant introduction (P.I.) numbers:

I

Bamboo Shoots Without Acridity

Of all the shoots tested, only the following were found to be entirely free from any unpleasant taste in the uncooked state:

P.I. No.	
38921	*Arundinaria simonii* var. *variegata*
128779	*Phyllostachys nidularia*
128812	*Phyllostachys nidularia* (cooked shoot has flavor of whole hominy)
77257	*Phyllostachys sulphurea* var. *viridis* (fragrant)
82047	*Phyllostachys vivax*
.....	*Pseudosasa japonica*

Another outstanding, semi-giant species that belongs in this category is *Phyllostachys dulcis* McClure, an early sprouting bamboo, all the shoots of which were too far advanced to be included in this particular test. It is the species of which the late Frank N. Meyer, agricultural explorer, wrote, " the edible bamboo grown in nearly every back yard in central China ".

Arundinaria simonii var. *variegata* and *Pseudosasa japonica* rarely, if ever, have shoots that are thick enough to be of practical value for food purposes, and even the larger ones of *Ph. nidularia,* judged from size alone, would seem scarcely large enough to be considered important as an article of food in comparison with the much larger shoots of the semi-giant and giant species. However, Dr. McClure assures me that in the regions of China in which *Ph. nidularia* grows, even the smaller shoots are everywhere used and highly prized, not only

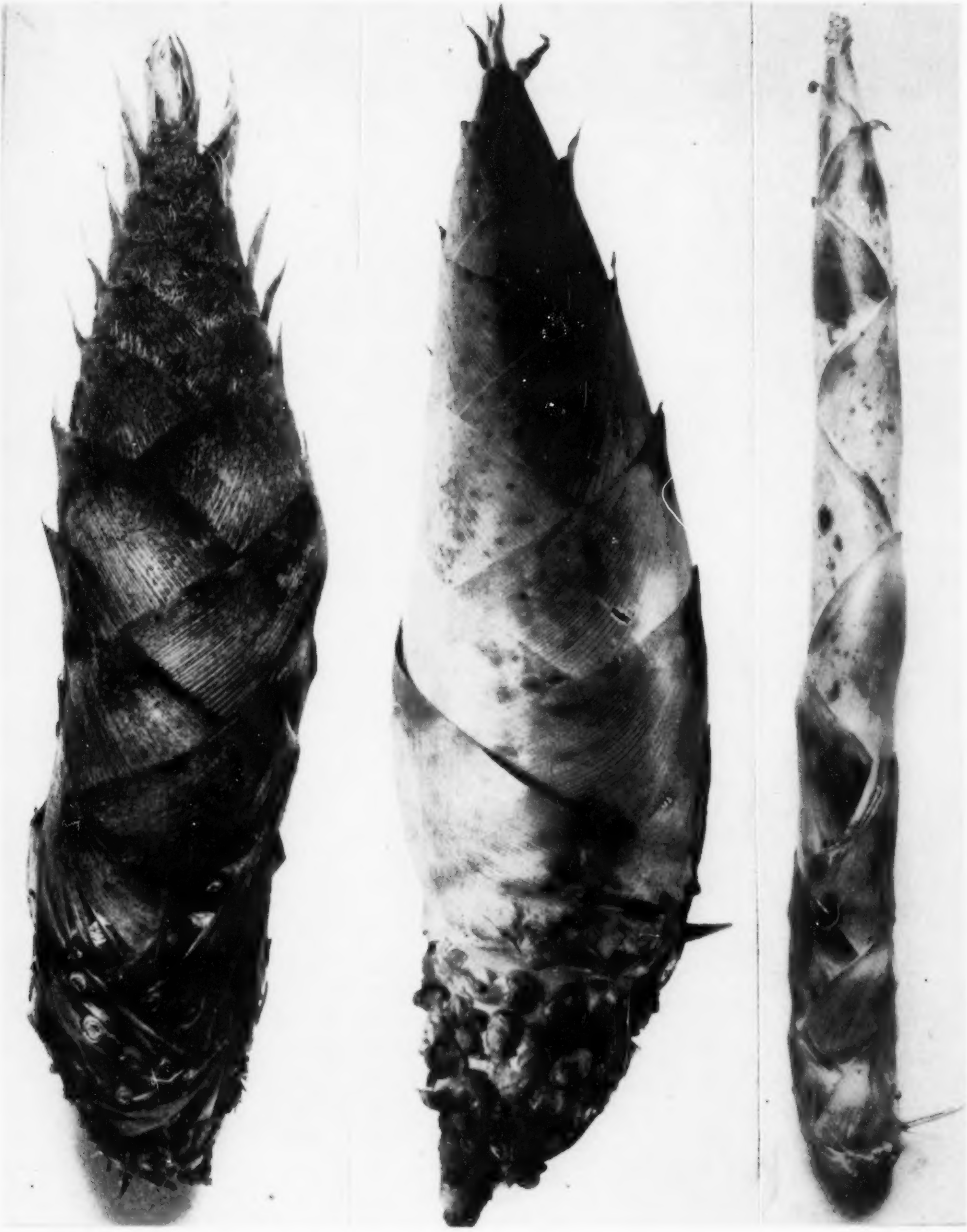

FIG. 2. Shoots or sprouts of three important edible bamboos: (*Left*). *Phyllostachys edulis* (Carr.) H. de L., the largest of the giant hardy bamboos, commonly known in China as " Mao tsoh " or " Mau chuk " and in Japan as " Mosochiku ". This shoot was 13 inches in length when dug.

(*Center*). *Phyllostachys bambusoides* Sieb. & Zucc., another of the giant hardy bamboos, variously called " Tae tsoh ", " Kang tsoh ", " Kwai chuk " and by other local names in China; in Japan it is commonly known as " Madake " or " Nigatake ". The shoot shown here was eight inches long and had about one-half of its length above ground when dug.

(*Right*). *Phyllostachys dulcis* McClure, a medium large, early sprouting, Chinese bamboo whose shoots are free from any trace of unpleasant taste, even when raw. In Chehkiang Province it is called " Pah koh poo chi " and is said to be the common vegetable bamboo grown nearly everywhere in central China. This shoot, 13 inches long, was elongated more than is desirable for cooking use, and considerable of the lower part had become woody; a root can be seen starting from the base.

because they are among the earliest to appear in spring but also for their delicate food qualities. The slightly hominy-like flavor that was noticed by persons who tasted the cooked shoots of this species in our tests seems not to be aromatic, and it was not detected in the raw shoots tasted. It is not at all unpleasing in the cooked shoots, and if larger shoots were produced the distinctive flavor probably would give them definite added value. The fragrance of the shoots of *Ph. sulphurea* var. *viridis* was slightly evident when the raw shoot was tasted, as well as during cooking and in the cooked product. Two other bamboos, *Ph. edulis* and *Ph. nigra* var. *henonis*, have much the same fragrance; it is most pronounced in the last named. Both are noticeably acrid when raw; *Ph. edulis* the more so.

II

Bamboos with Raw Shoots Having Varying Small Degrees of Acridity

P.I. No.		
75153	*Phyllostachys*	*aurea*
55713	"	*aureosulcata*
42659	"	*bambusoides* var. *castilloni*
80149	"	*congesta*
116965	"	*flexuosa*
66787	"	*nigra* var. *henonis*
103938	"	*nuda*
128791	"	*purpurata*
128800	"	*purpurata*
66902	"	*rubromarginata*
75154	"	*viridi-glaucescens*
77011	"	sp. (to be described as a new species)

In this group of species having slight acridity, I have recorded *P. aurea*, *P. aureosulcata*, *P. nuda* and *P. viridi-glaucescens* as being almost free of this quality.

III

Bamboos with Raw Shoots Having Considerable Acridity

P.I. No.		
40842	*Phyllostachys*	*bambusoides*
80034	"	*edulis*

There was not opportunity to test the edible qualities of the tips of the single long shoots of *Phyllostachys angusta*, P.I. No. 23237, and *P. propinqua*, P.I. No. 76649, received from Savannah, but no reason is known to doubt their edibility. The shoots of all species of this genus are believed to be edible.

General Comments

We did not receive any shoots of *Semiarundinaria fastuosa*, but Dr. McClure tells me that he cooked shoots of it from his own garden after his return from Savannah and found them to be of very good quality. He did not taste a raw shoot, and we are without knowledge as to any special flavor that it may have.

A cooking period of 18 to 20 minutes was found to be quite sufficient for the cut-up shoots of any bamboo not too far advanced for cooking. It is necessary always to discard a part of the base of a shoot because of the rapid development of fiber progressively upward in the shoot. Where the fiber seems not to be too much developed for edibility but yet is evident, I cut that part of the shoot crosswise into thin slices, not more than one-eighth inch thick, making them gradually thicker in moving upward on the shoot. After getting to where there seems to be virtually no fiber, I cut longer pieces, often cutting diagonally. Cooking the cut bamboo in one water is satisfactory when the bitterish or acrid taste is not strong, and even in *Phyllostachys bambusoides* and *P. edulis*, with their somewhat stronger-tasting raw shoots, cooking in one water (if in good quantity) will often remove practically all of the unpleasant taste; a change of

Fig. 3. View in a grove of *Phyllostachys bambusoides* at the United States Plant Introduction Garden near Savannah, Georgia, in late April when the new shoots were beginning to appear. Several of the edible shoots, a few inches high, can be seen in the foreground. This species is a native of China but has been cultivated for several centuries also in Japan.

water after eight to ten minutes of boiling is sure to give satisfactory results. Salt is added near the end of cooking, and butter or margarine can be used in further seasoning, especially if the bamboo is served as a hot dish. The cold cooked bamboo is excellent in a mixed salad—or even alone if a sufficient quantity is available.

All the bamboos reported in the foregoing are of the hardy genera *Arundinaria, Phyllostachys, Pseudosasa, Sasa* and *Semiarundinaria,* which are quite distinct in a number of respects from the more tender tropical types. I have had occasion in earlier years to test for their edible qualities the shoots of two tropical species grown in this country, and I shall include here the results as I recall them. The species were *Bambusa arundinacea* Retz., the great thorny bamboo of India, and *Sinocalamus beecheyanus* (Munro) McClure (*Bambusa beecheyana* Munro), the Beechey bamboo. The latter is said to be one of the principal edible bamboos of tropical and subtropical China. The new shoots of these warm-climate species appear in late summer or early autumn.

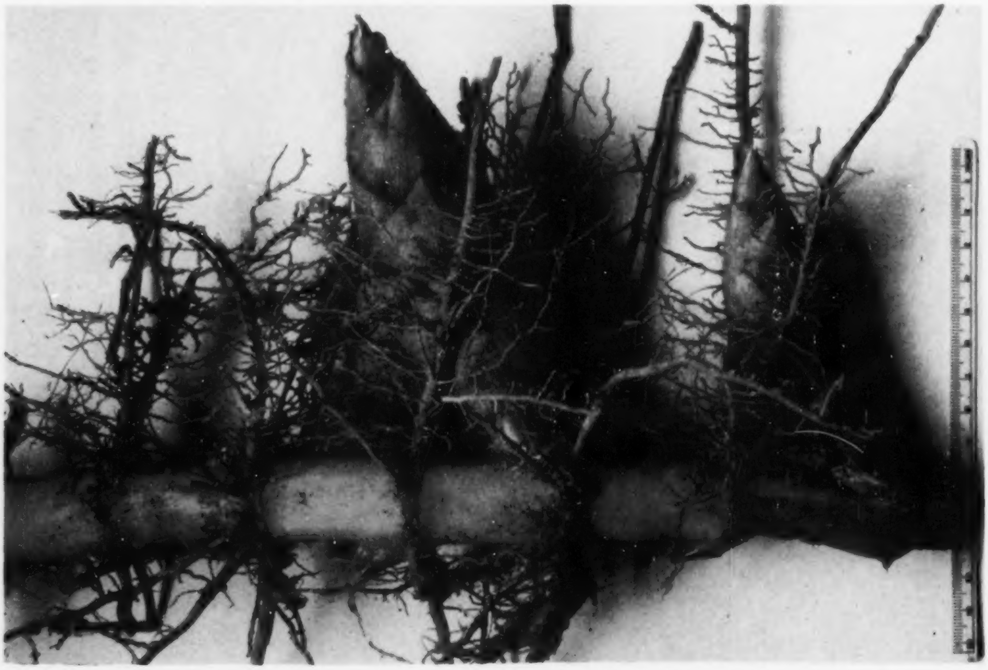

FIG. 4. An early stage of underground development of bamboo-shoot growth. This downward view of a section of a horizontal rhizome of *Phyllostachys edulis* shows the true roots still attached at the nodes and two swollen buds developing on one side, at alternate nodes, to form culm shoots (two shoots starting so close together is unusual and one of them may fail). This indicates in a general way the condition that would be found below ground three months earlier in the bamboo grove shown in Fig. 3.

The specimen shoot of *Bambusa arundinacea* tested was about three and one-half inches in diameter, and had grown to a length of perhaps 15 inches when cut. In the raw state it was very " bitter " or acrid, but with two changes of water in cooking the unpleasant taste was practically dispelled, and ordinary seasoning with salt and butter made the

FIG. 5. Some large culms of *Phyllostachys edulis* in a grove at Anderson, South Carolina, in mid-June, soon after the new ones completed their growth in height. These new culms, in the foreground, are distinguished by the whitish appearance of the internodes, due to a minute pubescence that later disappears. Distinct from this are the more permanent, characteristic glaucous bands beneath the nodes. *P. edulis* is the largest of the hardy bamboos but is slightly less hardy than some other giant species.

bamboo agreeably palatable. With somewhat larger volumes of water it is likely that one change would give satisfactory results. There was no distinctive flavor in the cooked product.

The testing of the other tropical species, *Sinocalamus beecheyanus*, was under such circumstances that no statement of edible or flavor qualities can be made on the basis of that test, but it will perhaps be of some interest to record here some observations. The test was made before it was clearly understood that in China the ground in and around the base of every clump of this bamboo being grown for shoots is mounded up well before the shoots are due to appear, so that light shall be completely excluded from them until they are dug. This is necessary to prevent development of chemical substances that give rise to an intensely disagreeable odor and taste in cooking. This, I found, was not removed except by such prolonged cooking as to render the product unfit for food. Since *S. beecheyanus* is reported to have endured temperatures down to 20° F. in southern California and is recognized as so important a source of edible shoots when properly grown (under mounded earth), it will doubtless be cultivated there and in southern Florida in the future to a much greater extent than now.

It has already been stated that young sprouts of all species of *Phyllostachys* grow in spring and are edible, so far as known, though many kinds always are small. The length of season for the sprouts of each kind usually is three to four weeks. Fresh young sprouts are crisp in texture both before and after cooking, and, as previously indicated, usually are without pronounced flavor. For the latter reason they probably will find more general acceptance cooked or served with substances having decided flavor, and the recipes that follow later were formulated with this in view. As to food value and vitamin content of bamboo sprouts, they appear not to be outstanding in any important respect. The average of a considerable number of analyses of many species from various bamboo-growing regions, as reported by the U. S. Bureau of Human Nutrition and Home Economics, shows 91 percent of water, with food energy of 27 calories per 100 grams of the edible part of sprouts. Total digestible carbohydrate is 4.5 percent; protein, 2.6 percent; fat, 0.3 percent; ash, 0.9 percent. As a source of phosphorus, the average analysis shows bamboo sprouts to be good as compared with other succulent vegetables; they rank with asparagus, mungbean sprouts, kale and spinach, but in calcium and iron they are low. The content of thiamin is relatively good and that of niacin fair, but of vitamin A, riboflavin and ascorbic acid, poor, according to the information.

Preparation of Bamboo Sprouts for Eating

Since relatively few people in this country are likely to have had experience in the cooking of bamboo sprouts, it seems appropriate in closing this report to reproduce some cooking directions prepared a number of years ago and formulated by the U. S. Bureau of Human Nutrition and Home Economics.

A bamboo sprout properly dug will have a rooty, woody, basal portion, increasing sharply in diameter upward for a short distance from the very slender part which was previously attached to the underground rhizome from which it grew, and then tapering to a point. With a sharp butcher knife, cut lengthwise *through the sheaths only*, from tip to base of sprouts. Beginning with the lower sheaths, remove all except the tender ones at the tip. If there is a grayish layer (due to age) next to the lower nodes (joints), pare this off and remove the tough basal part of sprout. Cut the core portion *diagonally* or *crosswise* into rather thin slices; the *lower,*

FIG. 6. View of a grove of *Phyllostachys nigra* var. *henonis* Stapf., the Hachiku of Japan, at the United States Plant Introduction Garden near Savannah, Georgia, showing the handsome foliage of this medium-giant bamboo of China and Japan. The edible shoots are fragrant when cooked. A pole marked at foot intervals appears at the right.

firmer portion should be cut across the grain and not thicker than an eighth of an inch, but the more tender middle and upper parts may be sliced thicker or may be cut into various shapes according to the recipe in which the material is to be used. For some salads, specially shaped pieces may be desired.

Bamboo sprouts first prepared as indicated above are used with excellent results as an ingredient in many ordinary dishes consisting of various vegetables with or without meat. They also may be served alone, drained, with butter melted over them, after boiling for about 20 minutes; salt is added near the end of boiling period. If the fresh sprouts are strongly bitter, there should be a change of water after the first eight to ten minutes of cooking. This simple method of cooking and serving is suggested for a first trial. For any of the recipes that follow, after stripping off the tough brownish sheaths and slicing or otherwise cutting the sprout into pieces, as previously directed, parboil for 15 minutes, season with salt near the end of the boiling period, and drain. Follow carefully the directions for slicing given in a preceding paragraph.

Sautéed Bamboo

2 tablespoons butter or other fat
3 cups sliced parboiled bamboo
1 teaspoon salt
Pepper

Heat the fat in a frying pan, add the bamboo, sauté for about five minutes until slightly brown, and stir occasionally. Add the seasoning and serve on hot cooked rice with a cheese sauce.

Scalloped Bamboo

3 cups parboiled sliced bamboo
4 tablespoons butter
4 tablespoons flour
2 cups milk
1 teaspoon salt
4 tablespoons grated cheese
Paprika

Place the bamboo in a greased shallow baking dish. Prepare a sauce of the butter, flour, milk and salt; then blend in the cheese. Pour this over the bamboo and bake in an oven at about 350° F. for 30 minutes. Serve with paprika sprinkled over the top.

Bamboo a la Creole

2 pounds beef steak, about 1½ inches thick
3 tablespoons flour
2 tablespoons fat
2 small onions, shredded
2 cups tomato
2 cups sliced parboiled bamboo
1½ teaspoons salt
⅛ teaspoon pepper
Parsley

Cut the steak into half-inch cubes and roll in the flour. Heat the fat in a frying pan, add the steak and the onions, and cook and stir until brown. Add the tomato, bamboo and seasoning, and turn into a casserole. Cover and cook in oven (350° F.) for about one hour. Sprinkle finely chopped parsley over the top and serve at once. Boiled rice is an excellent accompaniment.

Potato-and-Bamboo Salad

2 cups diced cooked potato
1½ teaspoons salt
½ cup French dressing
1 cup finely cut celery
1 cup finely cut parboiled bamboo
2 teaspoons chopped onion
1 cup cooked salad dressing
½ cup diced cucumber

Add the salt and the French dressing to the potato and chill. Add the celery, bamboo, onion and cooked salad dressing. Mix together carefully to avoid breaking the potato. Add the cucumber and serve on crisp lettuce. Bamboo may also replace the celery wholly or in part, if desired.

BOOK REVIEWS

Sugar Country—The Cane Sugar Industry in the South, 1753–1950. J. Carlyle Sitterson. xviii + 414 pages. Univ. of Kentucky Press. 1953. $6.

The first sugar cane to be raised in what today is the continental United States was produced in 1753 in the French Colony of Louisiana. From then until the close of the nineteenth century sugar was raised not only in the succeeding State of Louisiana but also, to some degree at least, in Florida, Georgia, South Carolina, Alabama and Mississippi. At no time during that period, however, did Louisiana account for less than 95% of the total sugar crop. In 1859 the total consumption of sugar in the United States, exclusive of California and Oregon, was estimated at 431,184 tons, of which approximately 130,000 tons were produced in the South. The peak was attained in 1861 with a record production of 459,410 hogshead of sugar, valued at more than $25,000,000 and produced on more than 1,200 plantations in 24 parishes. Within three years, by the end of 1864, the Civil War brought the industry to near collapse with a production of only 10,000 hogshead, valued at less than $2,000,000, on only 175 plantations in 16 parishes. Through 40 succeeding years of recovery the industry attained a peak production of almost 400,000 tons in 1904, and then declined to 50,000 in 1926 with complete collapse of the industry seemingly unavoidable. Again recovery took place, and in 1938 production reached an all-time high of more than 490,000 tons of raw sugar; 1950 witnessed the second high, a 456,000-ton crop.

Beginning with the Spanish period, sugar has been raised in widely varying amounts in Florida. From 1840 to 1849 production rose from 275,000 pounds to 2,750,000 pounds, but declined thereafter. That production was in various parts of the State north of Lake Okeechobee, but beginning about 1885 and continuing to the present day, drainage operations have opened the Everglades to the cultivation of sugar cane and many other crops. In 1950 production in this area amounted to 108,000 tons of raw sugar, and the sugar mill at Clewiston, with a daily grinding capacity of about 6,000 tons of cane, is the largest in the United States.

The history of this industry in the South, its many ups and downs, the economic factors controlling them, the people involved and technological advances, as well as various other aspects, are recorded in this study. Strictly botanical information is almost wholly absent from the book, being limited to passing mention of certain varieties of cane and their geographical origins as they played important roles in the industry. The book is not intended to be a botanical treatise and therefore cannot be criticized on that score; instead, it is the history of a plant-product-producing industry as it has developed in the United States, and as such it admirably fulfills its mission.

An Introduction to Industrial Mycology. George Smith. xiv + 378 pages. 4th ed. Edward Arnold (Publishers), London, England. 1954. $6.

Controlled fungal fermentations on a commercial scale have acquired progressively greater industrial importance in recent years, not only in the production of penicillin and of less important antibiotics from molds but also in that of enzyme preparations, of certain acids (oxalic, citric, gluconic, lactic, gallic, itaconic), fats and proteins, and of vitamins from similar microorganisms. The technology involved in such production, apart from matters of engineering, constitutes what is known as " industrial mycology ", for it is concerned with the biology and culture of the fungi utilized in these processes. But the various species of mold so used " differ in their responses to environmental conditions, in their abilities to attack various types of material, in toleration to antiseptics, and in synthetic activity. Hence little can be accomplished in the field of industrial mycology without a working knowledge of the moulds themselves, and the ability to recognize at least the more common species. Even in fermentation industries, which may

use a single species of fungus, contaminants are likely to cause trouble unless they are recognized at an early stage. In addition, it is essential to be able to distinguish a highly active strain from other less useful strains of the same species, and to be able to recognize that species when searching for new and more active strains ".

It is because of this background knowledge, so necessary for an industrial mycologist, that more than three-quarters of this " Introduction " to the subject is " devoted to descriptions and illustrations of most of the common species of moulds, and to the methods used in studying them for the purpose of identification ". Only 17 pages, three of them consisting of bibliography, constitute the chapter " Industrial Uses of Fungi ", containing brief accounts of the above mentioned and a few other industrially important applications.

An interesting, if not startling, viewpoint of the author is that fungi are not members of the Plant Kingdom but constitute a third Kingdom, co-equal with those of animals and plants. This, the author says, is the " modern view ". Actually it is not new, but is generally not emphasized.

Sweet Corn. Walter A. Huelsen. xv + 409 pages. Interscience Publishers. 1954. $10.50.

Bananas, apples and cocoa, and their various products, are three economically important crops which have been treated, each in a separate volume, in previous publications of a series known as " Economic Crops " by Interscience Publishers. The latest volume, IV, is devoted to sweet corn, a crop that is used exclusively for human nutrition without any byproducts except silage for cattle feed.

The breeding of hybrids, the physiology of germination and the nutrition of the growing plants are among the important technical aspects of the sweet corn industry considered in this book. The nutritional value of corn, the history and technology of canning operations and other non-botanical aspects are also considered. Of purely botanical content are 48 pages concerned with history, taxonomy and morphology.

The reader concerned with the origins of economically important plants will be especially interested in the following summary contained in these latter pages: " There are two theories regarding the origin of sweet corn. One considers it as a distinct species and a food plant of the North American Indian during the pre-Columbian era; the other identifies it as a mutation from field corn of relatively recent origin. Erwin discards the first theory, for with the exception of a single ear classed as a flint corn derivative of the Golden Bantam type, dated 1200–1300 A.D. and discovered in an Aztec ruin in New Mexico, no ear of sweet corn has appeared in the numerous collections of maize made by archeological expeditions. . . . Erwin, in support of the mutation theory of the origin of sweet corn, cites E. W. Lindstrom's discovery of a sweet mutant out of a corn pedigree under controlled pollination. Erwin apparently at first believed that sweet corn may mutate from flint, dent, or flour corn but recently has considered it a mutant of dent corn, having observed no mutation from flint. He considers the variety Golden Bantam as a flint corn, since a cross between it and dent produces a flint type. The theory that sweet corn originated as a mutant is plausible as it has been demonstrated that sweet corn is really field corn in an arrested state, due to the inability of the kernel to complete the formation of normal starch ".

Starch—Its Sources, Production and Uses. Charles Andrew Brautlecht. vi + 408 pages. 1953. $10.

Eight botanical sources—corn, white potatoes, sweet potatoes, cassava, wheat, rice, sago, arrowroot—furnish almost all the world's demand for starch, and of these the most important in terms of quantity is corn. Of minor importance locally in various areas of the world have been canna, chestnut, pea, rye, oats, bananas and the nodular roots of several varieties of orchid.

The uses of all these starches and the various steps in obtaining them from their respective botanical sources are extensively discussed in this book. The author is a chemist and chemical engineer, and the manufacturing processes, consequently, are emphasized in the volume. Nevertheless, the general, botanical and economic information also contained in it is abundant and renders the work of considerable reference value to more biologically inclined readers.